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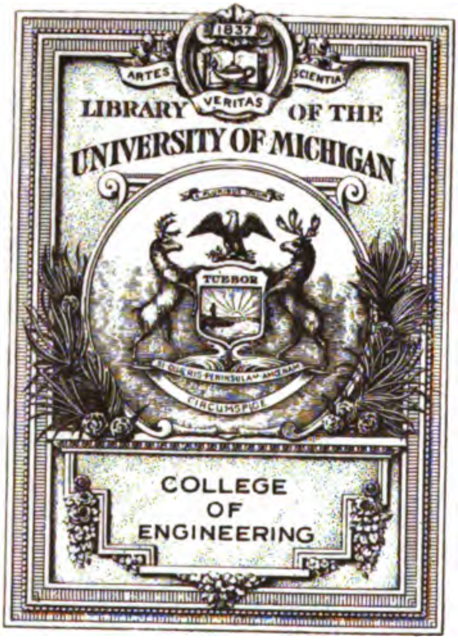

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OF
WAY AND STRUCTURES

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MAINTENANCE
OF
WAY AND STRUCTURES

BY

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PREFACE

A pronounced development has taken place during the past decade in the materials and appliances used in the construction and maintenance of railway-track. Changes in the composition and section of rails and the steady increase in the use of treated ties, following the scientific development of the timber-preserving industry, are notable examples. The use by American railways of tie-plates, rail-anchors, screw-spikes, steel ties, section motor-cars, etc., is so recent that a few of these are scarcely beyond the experimental stage. The Federal valuation of railways has been accompanied by new systems of accounting in the engineering as well as other departments and has placed greater responsibility upon the railway engineer. An accompanying development, though less pronounced, has taken place in the maintenance-of-way organization and in the methods of doing the work.

This book was undertaken with the idea of setting forth the best accepted practice of the day in that important branch of railway engineering, Maintenance of Way and Structures. The author has attempted to arrange the matter and treat it in such a way that it will be of interest both to the maintenance-of-way engineer and to the university student pursuing a course in engineering. Fundamental principles and theory are stated and are emphasized in each instance by representative examples of the practice of individual railways. An effort has been made to provide a very complete list of illustrations which considerably outnumber those published elsewhere. The index is arranged so that the relative importance of the references under each topic is at once apparent. The subject of signaling has been entirely omitted. Its wonderful recent development and wide adoption place it beyond the scope of this book. A separate volume should be devoted to its treatment.

The author wishes to thank the many railway officials, engineers, manufacturers, and others who have assisted him by supplying data or by criticism of the manuscript. He has endeavored to give credit to the works of others, to periodicals, and to societies and associations where credit is due. Frequent reference is made to the work of the American Railway Engineering Association which in a large measure is responsible for the present standardization of railway engineering practice.

November, 22, 1915. William C. Willard.

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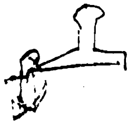

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MAINTENANCE OF WAY AND STRUCTURES

CHAPTER I

INTRODUCTION

1. Magnitude of the Railway Industry.—On June 30, 1914, considering all tracks—single track, second, third, fourth track, etc., yard tracks and sidings—in round numbers a total of 384,000 miles of track were being operated in the United States, 41,000 miles in Canada and about 20,000 miles in the remainder of North America, making a grand total of approximately 445,000 miles in North America. In order to emphasize the vast mileage this represents it will be stated in terms of the ciucumference of the earth. This track-mileage would girdle the earth seventeen times. The distance of the moon from the earth is 239,000 miles and this railway mileage is almost twice that distance. In the year from June 30, 1910 to June 30, 1911, 1,815,239 persons were required to maintain and operate the railways of the United States, 141,224 persons were required to maintain and operate the railways of Canada and about 75,000 those of the rest of North America. Considering Canada and the United States together, 1,956,463 persons were employed directly by the railways. The combined population of the two countries, according to the census taken during the year of 1910, was 99,178,909. This means that one person out of every fifty-one was directly supported by the railways. The individual figures for the two countries are one employe out of every 51 inhabitants, a surprising agreement of figures. A study of the report of the United States census for the year 1910 shows that the production of supplies directly consumed by the railways, but not manufactured by them, such as rails, ties, bridge steel, locomotives, cars, etc., required the employment of about 750,000 persons. In Canada the proportion is doubtless about the same, but if the number is assumed at only 50,000 the total number of persons directly and indirectly employed by the railways of the United States and Canada in 1910 was 2,756,000. The same census report gives the average number of persons per family in the United States as 4.5 in 1910. If it is assumed that but one out of each four persons employed directly or indirectly by the railways had the average family, 2,310,000 must be added, giving 5,066,000 as the number of persons supported by the railways. Dividing this into the total population it is seen that one person out of every twenty of our total population is dependent upon the railways for a living. These figures do not include electric roads or street-railways, but stand alone for steam-roads.

2. Maintenance of Way and Structures.—Let us now consider the keeping of this enormous track-mileage in a safe operating condition. This work of keeping in repair the track and its accompanying structures in properly called "Maintenance of Way and Structures," but is quite commonly abbreviated to "Maintenance of Way." Some idea can be had of the vast amount of work required and the importance of this work of maintenance, from the fact that almost one-third of all railway employees are on the work of maintenance of way and structures. The track is the fundamental part of this great railway system and it can easily be seen that the work of constantly maintaining this track in a safe operating condition is very important and requires unusual judgment, skill executive ability, and excellent organization.

At the very outset of a study of the work of maintenance of way two important facts must be understood, viz., (1) the large proportion of the operating expense which goes into expenditures for track maintenance, (2) the relation existing between the kind and condition of the track and the economic operation and business of the road.

The track and roadbed represent by far the greater amount of the investment, more than bridges and even terminals, except for a few very expensive terminals such as the Grand Central Terminal and the Pennsylvania Station in New York, the Kansas City Union Station, etc., yet as a branch of engineering, maintenance of way has in the past received scant recognition, much less than that received by other branches of no more importance.

In the past the work of maintenance was generally in the hands of a practical man who had worked up from the section-gang. The tendency at present is, however, to recognize more and more the engineering importance of the work and the necessity for placing experienced and trained engineers in charge of it. These men, who understand not only the practical side of the work but also the basic engineering principles, today are taking the place of the old-time practical roadmaster. The problem to be dealt with is complicated, involving heavy axle loads, high speed, a high grade of track construction and maintenance, and a very close economy.

3. Attitude of the Management toward Maintenance of Way Expenditures.—There is a tendency among railway managements to disregard recommendations from the maintenance of way department, particularly so if the company is short of funds and a policy of retrenchment is necessary. When it becomes necessary to reduce expenses the maintenance of way department suffers especially, for the management feels that the detrimental results of retrenchment will be less visible, at least to the public, here than elsewhere. The trains must continue to run and business must be sought and handled, so apparently the appropriations for the transportation and traffic departments can be reduced but little or not at all.

Consequently the maintenance of way department bears the brunt of the economy. In the long run it proves a very expensive economy. It is often thought that the resulting bad effects are confined to the track and structures, but a close observation of all expenses clearly shows that the neglect of maintenance of way is reflected directly in increased transportation expenses and increased expenses for maintenance of equipment. From lack of proper care the condition of the track rapidly deteriorates, ultimately making it necessary to decrease the train-load, and increases the cost of maintenance of equipment because of the increased wear and breakage due to rough track.

When it is absolutely necessary to cut expenses perhaps the management is justified in being particularly parsimonious with the maintenance of way department. But where retrenchment is not necessary, and yet the management regularly cuts down all recommendations from the maintenance of way department, this false economy results from the difficulty of seeing, or even computing, the financial saving in operation due to heavier rails, tie-plates, treated ties, better ballast, etc. It should be understood that the poorer the track in relation to the traffic, the greater will be the expense for maintenance and renewals because of the inability of the poor track to sustain the weights and shocks it receives.

Undoubtedly many railways are managed on more enlightened lines based on two fundamental principles: (1) the necessity for constant minor repairs and renewals to keep the track up to a standard condition by compensating for normal wear and depreciation; (2) the necessity for general improvement in the character of construction and maintenance in order to maintain the proper relation to the increasing density of traffic and heavier loads imposed upon the track.

4. Needed Railway Improvements.[1]—One of the most important duties of the maintenance of way engineer is to present clearly to the executive officials the desirability of improving the track as the traffic conditions become more serious. He should be able to show that a certain factor of safety is absolutely necessary and that better efficiency and a higher economy of the entire railway service can be obtained where the proper relation does exist between track and traffic. In any case, even though he cannot get the full appropriations he feels are needed, it is his duty to use that money which is available in such a way as to keep the road in the best possible condition for that expenditure.

Improvements for the purpose of facilitating the handling of traffic and getting it to its destination with the least possible delay and a greater degree of safety also are much needed at present. Such improvements would consist of revision of alignment, grade reduction, double-tracking, the installation of block signals and interlocking plants, the construction of more passing sidings on single-track lines, additional and improved fuel and water stations, and perhaps of more importance than all others, the revision and enlargement of yards and terminals. The necessity for greater track capacity and larger and better-operated yards and terminals is never appreciated until a period of traffic congestion actually occurs. The necessity for installing proper signals or for double-tracking is more imperative than for building additional branch lines which would only bring more traffic to the already overtaxed main line.

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[1] **See page 8, Railway Track and Track Work, by E. R. R. Tratman.**

The delay of a car in any one divisional yard often is from 10 to 20 hours and under adverse conditions several times this period, particularly if minor repairs to the car are necessary or if the car has to be transferred from one yard to another. Where the car journey is long and the car passes through several yards the total car delay may amount to several days. There are probably but few yards where a close study of arrangement and method of operation would not show many points where improvements could be made and car delay reduced.

The discussion of many of these improvements more properly comes under the subjects of location and construction, operation, signaling, etc., and cannot be taken up in this work which treats more particularly with the maintenance of way department, its organization, materials, methods and costs.

5. Relation between Construction and Maintenance of Way.—Construction and maintenance of way are very closely related. It is further exemplified here that the transgressions of the father fall on the child. In constructing a new railway the construction department is the father of the maintenance department. The latter does not come into existence until construction is completed and the organization of the former is largely disbanded. Long afterward errors in construction fall heavily upon the maintenance department. The fact that the construction department first existed is responsible for the engineering organization on many railways, in which the maintenance department is given a second rate and placed as a branch of the general engineering or construction department. As a matter of fact, after construction is completed the maintenance department is more important than the construction department except where extensive betterment work is being carried out. It might be said that the importance of the construction department fluctuates while that of the maintenance department is always high.

That portion of the total operating expenses represented by maintenance of way on American and Canadian railways has always been high. This is accounted for to a considerable extent by the fact that when most railways were first built the railway was completed considerably in advance of the prospective business, and immediate cheapness and rapidity of construction were required, rather than ultimate economy of operation. In most cases this basis of construction was warranted, but the present trouble is due to the fact that in many instances the business of the road has increased enormously while the original cheap and light character of construction has never been improved. In such a case it can only be expected that maintenance costs will be high.

6. Classification of Track on a Traffic Basis.—The construction and maintenance departments of every railway have certain standards for material and methods. On any railway these may have been changed from time to time to better meet traffic conditions, improvements in devices or increased cost of material. Unfortunately the change has not always been for the best. A discussion of these standards of construction will be taken up later. It must be understood, however, that because it is said a certain railway has a standard 100-lb. rail laid on tie-plated ties, rail-braces on all curves, 12 in. of broken stone ballast under ties, etc., it does not mean that every mile of track of that road is so equipped. What it generally does mean, is, that when it becomes necessary to replace any of the old material on main track, the new material used is of the adopted standard.

A railway having an extended mileage has a variety of different kinds of track and many different traffic conditions. Thus the maximum freight-train, the fast freight-train, and the high-speed passenger-train, all with excessively heavy axle loads and total weight, in making their run pass over several kinds of track some of which undoubtedly will not be up to the standard for such traffic. Even when all materials are the same the work done by different section-gangs is not exactly the same in standard of excellence. The result of these maximum trains traveling over inferior track is excessive injury to the track as well as injury to the rolling-stock. Under such conditions the cost of maintenance is high and the factor of safety low. Rails are more rapidly worn and more liable to break, rail-joints work loose and soon become low, ties become rail-cut, spikes are pulled, soft ballast is crushed, frogs and switch-points are battered, the rails are spread and the track is thrown out of line and surface. Besides the increase in the cost of material for renewals there will be a decided increase in the various items of work required on the track.

The American Railway Engineering Association has adopted the following classification of track on a basis of traffic carried:

Class A Track.—All districts of a railway having more than one main track. Also all single-track districts where the traffic equals or exceeds a freight-car mileage of 150,000 per mile per year; or a passenger-car mileage of 10,000 per mile per year and a maximum passenger-train speed of 50 miles per hour.

Class B Track.—All single-track districts of a railway where the traffic is less than for Class A and is equal to or exceeds a freight-car mileage of 50,000 per mile per year; or a passenger-car mileage of 5000 per mile per year and a maximum passenger-train speed of 40 miles per hour.

Class C Track.—All districts of a railway not meeting the traffic requirements of Classes A or B.

7. The Cost of Railway Track.—The cost of several items of track-construction varies within wide limits, being affected by the character of workmanship, the character of the country traversed, the facilities for distributing materials, and the existing market rates of labor and materials.

TABLE 1.—COST OF RAILWAY-TRACK IN THE STATE OF WASHINGTON

Item	Cost per mile of line				
	Original cost of Great Northern Ry.[a]	Cost of reproduction of Great Northern Ry. in Washington in 1906[a,b]	Original cost of Fairhaven Southern Ry.[c]	Estimated original cost of the Spokane Falls and Northern Ry.[d]	Original cost of the Washington and Great Northern Ry.[e]
Bridges and culverts	$4,318	$5,024	$4,196	$1,164	$3,623
Cattle-guards, road crossings and signs	234	242	7	24	17
Ties	1,198	1,870	751	1,612	1,035
Rails	5,932	5,126	4,303	4,031	5,261
Rail-fastenings	774	1,001	498	791	700
Frogs, switches, etc.	169	107	16	70	161
Track laying and surfacing	532	872	396	835	866
Ballasting	1,088	1,148	653	600	1,024
Surfacing, lining and filling track	61	....	....	....	34
Fences	22	105	121	63	50
Protection against snow and ice	158	282	....	....	....
Fuel and water stations	258	310	273	147	389

[a] 488 miles of line in State of Washington, including 488 miles of single track and an additional 8 per cent. for sidings. Built 1891–1894.

[b] Estimated by H. P. Gillette.

[c] 32.3 miles.

[d] 130.5 miles of line, including 130.5 miles of single track and 20.79 miles of sidings. Built in early 90's.

[e] Built by the Great Northern Ry. Completed in 1906. 83.9 miles of line, including 83.9 miles of single track and 7.89 miles of sidings.

Several years ago the railway commission of the State of Washington conducted an investigation under Mr. H. P. Gillette, chief engineer, into the cost of railways within the state. In Table 1 are given those results of this investigation as to the cost of the track which are of most interest to the maintenance engineer. The cost of constructing 488 miles of the Great Northern Railway across the State of Washington was only $44,400 per mile, including all expenses except rolling-stock. This included a tunnel 13,813 ft. long through the Cascade Mountains. The cost of engineering was 3 per cent. of the total.

8. Expenditures on Track Maintenance.—The results obtained from expenditures on track maintenance are often unsatisfactory from an economic standpoint, due to a failure to realize the governing conditions. On practically every railway money is spent over and over again upon the same stretch of track without producing any permanent improvement. This is for the constant work necessary to repair the track from the effect of traffic and bring it up to a point near to its normal condition, but no permanent advance is made in its condition. It should be clearly understood that large and immediate expenditures on radical or permanent improvements in maintenance standards and materials may affect important economies in maintenance expenses just as a reduction of grade and curvature will reduce transportation expenses.

Thus it is seen that the maintenance of a proper relation between track and traffic is essential for true economy, but if a lack of balance does exist, it is not an argument against the development of transportation or operating methods. The entire purpose of a railway is to carry traffic, and the machinery of operation, that is, the weight of locomotives and cars, the length, number and speed of trains, will be governed by the amount of business that the road gets. Certainly the policy of the road should not be to turn away business and reduce weights of trains to fit the track, but on the contrary the track should be made to fit the traffic, since it is the traffic that earns the revenue.

Prior to July 1, 1914, the Interstate Commerce Commission provided for twenty-three individual accounts under Maintenance of Way and Structures. One of these, that of maintaining joint tracks, yards and other facilities, was a credit account. Canadian railway accounts for Maintenance of Way and Structures were kept in the same way except that the credit account was omitted. The percentage of all Maintenance of Way and Structures expenses to total operating expenses on American and Canadian railways for the 5-year period 1909–1913 was 19.132 and 21.126 per cent. The figures given first in each case are the average for all Class 1 American roads, that is, roads having an annual operating revenue of $1,000,000 or more, and those given second are the average for all Canadian roads. Maintenance of equipment was 22.968 and 20.470 per cent. and transportation expenses 51.154 and 51.394 per cent. Considering the individual items which go to make up the total maintenance of way expense, almost half the total, or 7.180 and 8.882 per cent., was for "roadway and track" which includes the work of resurfacing, relining, redriving spikes, tightening bolts, etc. The second largest

TABLE 2.—PROPORTION OF MAINTENANCE EXPENSES TO OPERATING EXPENSES OF INDIVIDUAL RAILWAYS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Road	Miles of line	Miles of all tracks except yards and sidings	Miles of all tracks operated	Per cent. of op'n'g. exp. to total op'n'g rev.	Operating revenue per mile of line	Operating expenses per mile of line	Operating expenses per mile of all tracks operated	Per cent. of M. of W. & S. to total op'n'g exp.	Cost of M. of W. & S. per mile of line	Cost of M. of W. & S. per mile of all tracks ex. yds. and s'd'gs.	Cost of M. of W. & S. per mile of all tracks operated	Per cent. of yds. and s'd'gs. to miles of line	Per cent. of yds. and s'd'gs. to miles of all tracks except yds. and s'd'gs.
C. P.	10,750	11,504	14,415	64.8	10,813	7,013	5,230	23.5	1,648	1,543	1,229	27.1	25.3
G. T. G. T. C. A.	3,574	4,268	5,525	71.2	10,625	7,569	4,860	15.9	1,207	1,010	780	35.2	29.5
C. N. C. N. C. N. O. C. N. Q.	4,538	5,207	5,811	70.9	5,084	3,606	2,816	18.6	672	585	524	13.5	11.8
Can. Gov. Rys.	1,773	1,837	2,248	98.5	6,420	6,323	4,987	17.3	1,096	1,058	865	23.2	22.4
All Canada	26,727	28,480	34,629	68.7	8,209	5,640	4,353	20.9	1,179	1,107	910	23.0	21.6
P. R. R.	4,021	6,391	10,267	71.9	40,834	29,371	11,503	15.7	4,681	2,970	1,810	96.4	60.7
N. Y. C.	3,595	5,933	8,893	73.3	29,095	21,334	8,624	18.8	3,856	2,337	1,559	82.3	49.9
B. & O.	4,455	5,904	8,751	69.9	20,784	14.525	7,395	17.6	2,551	1,925	1,299	63.9	48.2
L. & N.	4,741	4,912	6,653	70.5	11,857	8,358	5,956	22.3	1,862	1,797	1,327	36.7	35.4
I. C.	4,763	5,689	7,655	81.9	12,330	10,103	6,286	15.9	1,615	1,352	1,005	41.3	34.5
Southern	7,090	7,462	9,723	68.7	8,969	6,163	4,494	17.9	1,106	1,051	806	31.9	30.3
N. & W.	2,018	2,439	3,539	64.6	19,690	12,720	7,253	18.8	2,386	1,975	1,361	54.5	45.1
C. B. & Q.	9,074	9,859	12,638	69.9	9,447	6,684	4,799	22.3	1,492	1,374	1,071	30.6	28.2
S. P.	6,310	6,643	9,049	57.4	14,361	8,244	5,749	19.5	1,604	1,524	1,119	38.1	36.2
A. T. & S. F.	8,201	9,028	11,916	64.2	10,957	7,032	4,839	23.2	1,628	1,478	1,120	35.2	31.9
U. & P.	3,575	4,302	5,570	57.9	13,199	7,640	4,904	17.9	1,375	1,143	882	35.5	29.5
C. & N. W.	7,961	9,028	12,335	71.5	9,257	6,633	4,273	17.8	1,177	1,038	760	41.5	36.6
U. S. Class I	220,063	249,193	336,455	69.2	12,471	8,628	5,643	18.4	1,584	1,358	1,036	39.7	35.0

item was for tie-renewals and was 3.061 and 2.636 per cent. of the total operating expense; third, buildings, fixtures, and grounds was 1.757 and 2.206 per cent.; fourth, bridges, trestles, and culverts was 1.565 and 1.506 per cent.; fifth and seventh, other track material was 1.034 and 0.916 per cent.; seventh and fifth, renewals of rails was 0.923 and 1.249 per cent. The remaining items, which represent ballast, repairs and renewals to fences, signs, docks and wharves, telegraph and telephone lines, signals and interlocking; stationery and printing, superintendence, other expenses, etc., constitute the remaining balance of 3.612 and 3.734 per cent.

The above percentages are average values for all railways in each of the countries, considered as one system. A more instructive method is to investigate the expenditures of a certain railway and compare them with figures for similar expenses of other railways. In Table 2 is given a comparison of maintenance of way and structures expenses with operating expenses of several individual railways in the United States and in Canada for the year ending June 30, 1912. From a study of the table the following conclusions may be drawn:

CONCLUSIONS FROM TABLE 2

1. The statistics for American and Canadian railways agree so closely in most cases that operating conditions in the two countries can be considered as practically identical.

2. With the ratio of operating expenses to total operating revenue of 98.5 per cent. (102.2 per cent. in 1913) for the Canadian Government Railways, the natural conclusion is that politics is in a measure responsible, and that Government Ownership, in this case at least, is inefficient.

3. The values given in columns 5, 8, 9, 10, 11 and 12 agree remarkably well for the individual railway and country averages given. The railways given for the United States were selected only with a view to show representative railways for each section of the country. Those for Canada are the four largest Canadian systems.

4. The percentage of yard tracks and sidings to other tracks in Canada is low and must rapidly increase for the railways to satisfactorily handle their traffic.

5. The effect of heavy traffic upon the cost of maintenance of way is clearly shown in the case of the Pennsylvania, the New York Central, the Baltimore and Ohio, and the Norfolk and Western. The total operating revenue and operating expense is the highest for these four railways, and their cost of maintenance per mile of line, per mile of all main tracks, and per mile of all tracks, is the highest.

6. From column 11 the cost of maintenance per mile of main track, or all tracks except yard tracks and sidings, is $1543 for the Canadian Pacific; $1352 for the Illinois Central; $1374 for the Chicago, Burlington and Quincy; $1524 for the Southern Pacific, and $1478 for the Atchison, Topeka and Santa Fe. These railways have an all track mileage ranging from 5689 to 11,504 miles, are located in widely separated parts of the continent, and are operated and maintained under radically different climatic conditions and systems of organization.

Yet the cost of maintenance per mile of main track differs but $191 for any of the five. The figures given for all tracks agree even closer.

7. On an average, the cost of maintenance of way and structures is about 19.0 per cent. of all operating expenses for large railway systems.

8. On an average, for all tracks it costs about $5600 to operate 1 mile of track per year.

9. On an average, for all tracks it costs about $1000 per year to maintain 1 mile of track. For very heavy traffic this may be increased 100 per cent.

10. On an average, for all main tracks it costs about $1300 per year to maintain 1 mile.

11. For Class A railways the yard- and side-track mileage should be not less than 40 per cent. of the single-track or road mileage.

12. On an average, over two-thirds (about 69 per cent.) of all operating revenue is spent in operating expenses.

In analyzing the expenses of the maintenance of way department, where the cost of labor is found to be above the average for other similar roads, the indication is that the track has not been strengthened in due proportion to the increased loads imposed upon it by (*a*) heavier axle loads, (*b*) higher speeds, and (*c*) denser traffic. Therefore, among his other duties, the maintenance of way engineer must keep a close watch upon the account sheet of the railway. By carefully analyzing the expenses and by comparing them with those of other railways and other parts of the same railway, the weak point may be found.

CHAPTER II

ORGANIZATION AND RULES

9. Principles of Organization.—Organization is the direction of the efforts of a number of individuals to a common purpose. The best results and greatest economy can be obtained in any undertaking requiring the services of a number of persons, only by organizing and coordinating the several individuals into a composite unit under the direction of one master mind. The greater the number of individuals in the organization, the more complex will be the organization. Any business man, contractor, manufacturer, or engineer whose duty it is to direct the energies of a body of individuals must, therefore, understand the basic principles of organization.

In forming an organization for a specific purpose it is necessary first to clearly define the objects to be accomplished by the organization and, second, to ascertain what tends to aid in or retard the accomplishment of these objects. The more important principles to be observed in order to obtain a successful organization may be stated in the following seven rules:[1]

1. At all points where action or decision must be taken, centralize authority in one person. A division of authority encourages an evasion of responsibility.
2. Definitely outline the authority and responsibility of each position. Uncertain boundaries of authority lead to conflict and ill-feeling.
3. The duties of each position must be made to conform to the capabilities of the incumbent. This may often best be done by changing the incumbent.
4. One person should not be made subordinate to two or more others, especially in regard to matters closely related.
5. The disciplinary authority should be placed in the same hands as the responsibility.
6. The work of administration should be distributed in such a way as to avoid unequal loading of the different officers.
7. There should be no positions which do not permit of promotion therefrom. Otherwise there is no incentive for the occupant of such a position to put forth his best efforts.

In following these principles two things must be constantly kept in mind; namely, (1) the individual is the most important unit in any organization, and (2) nothing makes a man so conservative as responsibility. The former is lost sight of in many cases, but always to the detriment of the organization. The work of the organizer is only well started when the organization is outlined and the occupants selected for the positions. A constant work of education must be carried on. The individual must be instructed in the proper performance of his duties and must be developed so that later he may be capable of occupying a more responsible position. The future success of the organization depends almost entirely on this work of development and promotion. Also, each individual must be taught to work in harmony with his fellow workers. This *esprit de corps* is an intangible but very important part of a successful organization.

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[1] Economics of Railway Operation, by Mr. M. L. Byers.

One of the most difficult tasks in outlining any organization is to correlate the activities of the outside workers with the necessary correspondence, records, and accounting on the inside. The man out on the job always has his troubles with the man in the office, but much of the friction will be avoided if the man in the office has a first-hand knowledge of the work outside.

10. General Organization of Railways.—The organization and bylaws of most railways provide for four general departments:

1. Executive, financial, and legal.
2. Traffic.
3. Operating, including maintenance and construction.
4. Accounting and auditing.

A vice-president is generally at the head of each of these.

On a basis of business as it is actually conducted, the work of a railway naturally divides itself into eight distinct departments:[1]

1. Legal, furnishing legal advice and protection.
2. Traffic, which has to do with the soliciting of business and fixing of rates.
3. Treasury, having charge of all funds.
4. Accounting and auditing, which records and examines all transactions.
5. Operating, which manufactures the transportation offered for sale by the traffic department.
6. Maintenance of equipment.
7. Maintenance of way. Maintenance of way and maintenance of equipment together represent the care and repair of the machinery that manufactures the transportation.
8. Betterment, which improves and enlarges the transportation machine.

The work of railway operation is a continuous performance and, unlike other industries, the plant is spread over hundreds or thousands of miles of territory. Because of the extent of territory covered, a railway has less control over its employees than has any other kind of organized effort. This has resulted in the evolution of two essentially different systems of organization, known as Departmental and Divisional, each having certain advantages and disadvantages not possessed by the other.

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[1] Mr. M. L. Byers, in his "Economics of Railway Operation," classifies the work under seven departments, maintenance of way and maintenance of equipment being combined. In "Railroad Administration," by Ray Morris, the classification is as follows: (1) traffic, (2) operating, (3) civil engineering, (4) mechanical, (5) financial, (6) purchasing, and (7) legal.

The former always has been the prevalent system of organization in Great Britain. The latter is in more common use in the United States, although most American railway organizations are neither clearly divisional nor clearly departmental. The operating—including transportation—maintenance of equipment, and maintenance of way departments are usually on the divisional basis, while the legal, treasury, accounting, traffic, and betterment departments more nearly correspond to the departmental system.

11. Departmental Organization.—In the departmental system of organization, one working organization is extended over the entire territory, each department being territorially subdivided. Each territorial subdivision of a department is placed in charge of an officer who reports to the head of the department. The chief executive's staff is composed of these heads of departments.

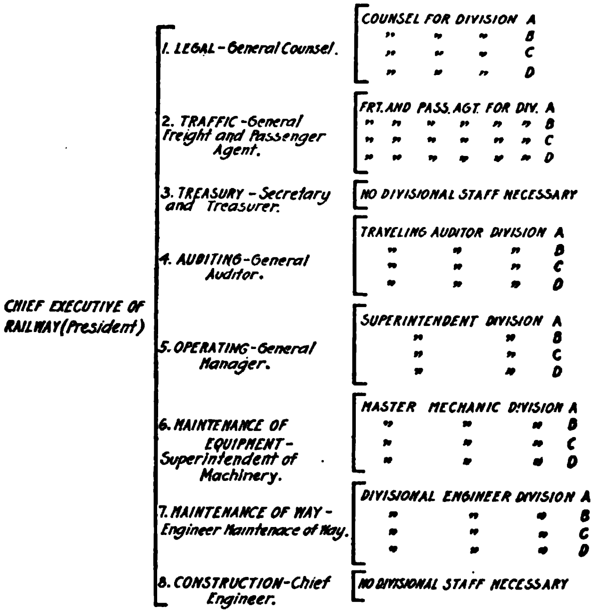
CHIEF EXECUTIVE OF RAILWAY (President)
1. LEGAL - General Counsel.
COUNSEL FOR DIVISION A
" " " B
" " " C
" " " D
2. TRAFFIC - General Freight and Passenger Agent.
FRT. AND PASS. AGT. FOR DIV. A
" " " " " " B
" " " " " " C
" " " " " " D
3. TREASURY - Secretary and Treasurer.
NO DIVISIONAL STAFF NECESSARY
4. AUDITING - General Auditor.
TRAVELING AUDITOR DIVISION A
" " " B
" " " C
" " " D
5. OPERATING - General Manager.
SUPERINTENDENT DIVISION A
" " B
" " C
" " D
6. MAINTENANCE OF EQUIPMENT - Superintendent of Machinery.
MASTER MECHANIC DIVISION A
" " " B
" " " C
" " " D
7. MAINTENANCE OF WAY - Engineer Maintenance of Way.
DIVISIONAL ENGINEER DIVISION A
" " " B
" " " C
" " " D
8. CONSTRUCTION - Chief Engineer.
NO DIVISIONAL STAFF NECESSARY

FIG. 1.—Ideal departmental organization for a large railway.

There is always a certain amount of work on any division that cannot be done entirely by one department, as for example, the transportation department has charge of trains and crews while on the road, but the maintenance of equipment department has charge of the cars and repair of the cars, engines, etc. If the heads of departments do not act in harmony, it is much farther up the line to a common superior in a departmental than in a divisional organization, and hence the chance for investigating and removing the cause of friction is more remote. Also, the head of each department must rely on subordinates who are far removed from his oversight. The ideal departmental organization for a large railway is shown in Fig. 1.

12. Divisional Organization.—The divisional system of organization is based on a territorial subdivision of the entire railway property, giving each division a more or less complete organization under an executive. As mentioned in Art. 10, in practice this system is never used in its theoretical form because a divisional organization for every department is unnecessary. In the theoretical organization each division executive has reporting to him a staff of experts in all of the different departments, but the chief executive of the railway has reporting to him only a staff of division executives who at best are only experts in one or two departments. In practice this condition has brought about the necessity for adding to the staff of the chief executive a staff of experts in advisory capacity. The relation of the advisory experts to the divisional experts immediately becomes a source of trouble. The ideal divisional organization for a large railway is shown in Fig. 2. The divisional system is more expensive to maintain than the departmental.

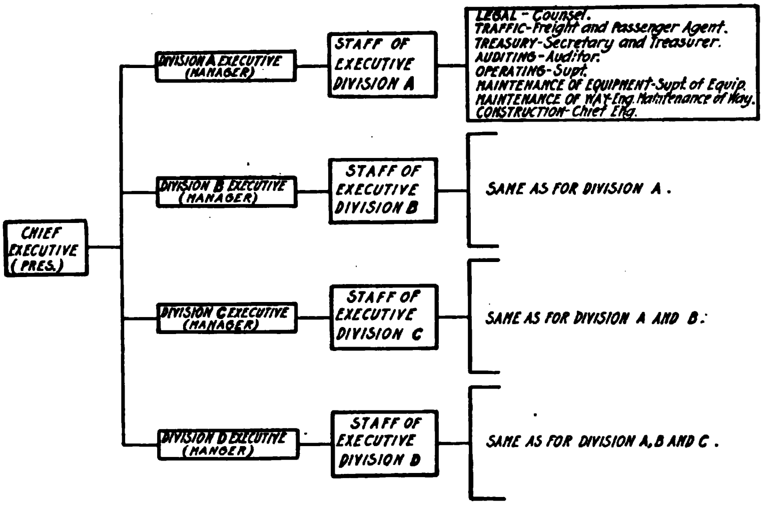
CHIEF EXECUTIVE (PRES.)
DIVISION A EXECUTIVE (MANAGER)
STAFF OF EXECUTIVE DIVISION A
LEGAL - Counsel.
TRAFFIC-Freight and Passenger Agent.
TREASURY-Secretary and Treasurer.
AUDITING-Auditor.
OPERATING-Supt.
MAINTENANCE OF EQUIPMENT-Supt. of Equip.
MAINTENANCE OF WAY-Eng. Maintenance of Way.
CONSTRUCTION-Chief Eng.
DIVISION B EXECUTIVE (MANAGER)
STAFF OF EXECUTIVE DIVISION B
SAME AS FOR DIVISION A.
DIVISION C EXECUTIVE (MANAGER)
STAFF OF EXECUTIVE DIVISION C
SAME AS FOR DIVISION A AND B.
DIVISION D EXECUTIVE (MANGER)
STAFF OF EXECUTIVE DIVISION D
SAME AS FOR DIVISION A, B AND C.

Fig. 2.—Ideal divisional organization for a large railway.

On the Western Lines of the Canadian Pacific Railway, which is organized on the divisional plan, there are three districts, each averaging 475 miles in length and being in charge of a general superintendent who has reporting to him a resident engineer, district master mechanic, master of bridges and buildings, chief train dispatcher and roadmasters.

13. The Unit System of Organization.—In 1909 the Union Pacific System and the Southern Pacific Company commenced to install a modified form of the divisional organization, termed the "Unit" system. The significant facts differentiating the unit system from the ordinary divisional system are, (1) the elimination of distinctive titles of all divisional departmental heads, such as Master Mechanic, Division Engineer, Train-master, Chief Dispatcher, etc., making each of these an Assistant Superintendent equal in authority to all others of the same title; (2) an experienced man, the senior assistant, acting as chief of staff, must remain at headquarters at all times, and (3) a consolidation of divisional departmental offices into a common office, with a consolidated file, for all division subordinates or assistant superintendents. A large volume of inter-office correspondence is eliminated by consolidating the offices. By making each assistant superintendent responsible in a measure for work of all kinds a greater efficiency is obtained by avoiding the shifting of responsibility from one department to another. The Division Superintendent is really the general manager of his division. He reports to the Chief Engineer, the General Superintendent, etc. The elimination of distinctive titles did not meet with the approval of many of the men concerned and the present extent of this form of organization is quite limited.

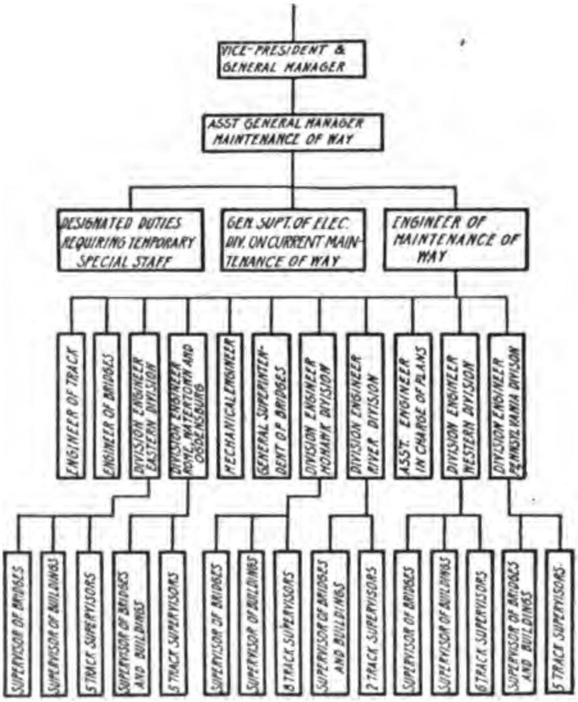
VICE-PRESIDENT & GENERAL MANAGER
ASST GENERAL MANAGER MAINTENANCE OF WAY
DESIGNATED DUTIES REQUIRING TEMPORARY SPECIAL STAFF
GEN. SUPT. OF ELEC. DIV. ON CURRENT MAINTENANCE OF WAY
ENGINEER OF MAINTENANCE OF WAY
ENGINEER OF TRACK
ENGINEER OF BRIDGES
DIVISION ENGINEER EASTERN DIVISION
DIVISION ENGINEER ROME, WATERTOWN AND OGDENSBURG
MECHANICAL ENGINEER
GENERAL SUPERINTENDENT OF BRIDGES
DIVISION ENGINEER MOHAWK DIVISION
DIVISION ENGINEER RIVER DIVISION
ASST. ENGINEER IN CHARGE OF PLANS
DIVISION ENGINEER WESTERN DIVISION
DIVISION ENGINEER PENNSYLVANIA DIVISON
SUPERVISOR OF BRIDGES
SUPERVISOR OF BUILDINGS
5 TRACK SUPERVISORS
SUPERVISOR OF BRIDGES AND BUILDINGS
5 TRACK SUPERVISORS
SUPERVISOR OF BRIDGES
SUPERVISOR OF BUILDINGS
8 TRACK SUPERVISORS
SUPERVISOR OF BRIDGES AND BUILDINGS
7 TRACK SUPERVISORS
SUPERVISOR OF BRIDGES
SUPERVISOR OF BUILDINGS
6 TRACK SUPERVISORS
SUPERVISOR OF BRIDGES AND BUILDINGS
5 TRACK SUPERVISORS

FIG. 3.—Maintenance of way organization, N. Y. C. & H. R. R. R.

14. General Organization of the Maintenance of Way Department.—The organization of the maintenance of way department and the methods of doing the various kinds of work have changed very little during the past 40 or 50 years. As most other branches of railway activity show marked improvement this can only mean that development in the maintenance department has not kept abreast of the general development in the science of railroading. Recently several railways have taken up the matter of reorganizing the maintenance of way department and a few radical changes have been made, such as rearranging the work so as to secure a permanent organization of the section forces, instituting a premium system, and the adoption of improved track tools and machines.

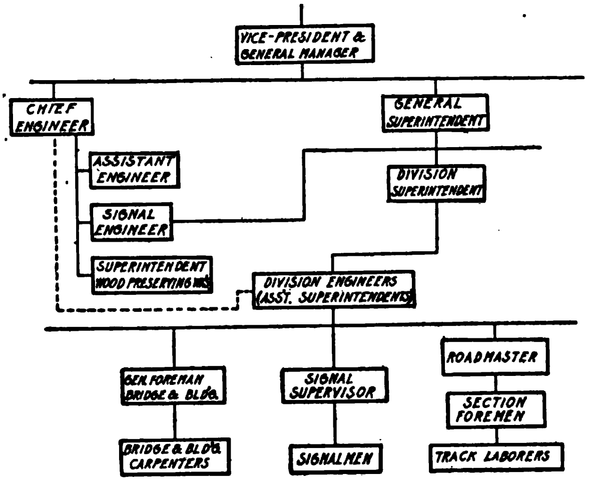
VICE-PRESIDENT & GENERAL MANAGER
CHIEF ENGINEER
GENERAL SUPERINTENDENT
ASSISTANT ENGINEER
DIVISION SUPERINTENDENT
SIGNAL ENGINEER
SUPERINTENDENT WOOD PRESERVING WKS
DIVISION ENGINEERS (ASST. SUPERINTENDENTS)
ROADMASTER
GEN. FOREMAN BRIDGE & BLDG.
SIGNAL SUPERVISOR
SECTION FOREMEN
BRIDGE & BLDG. CARPENTERS
SIGNALMEN
TRACK LABORERS

FIG. 4.—Maintenance of way organization, Union Pacific Railroad and Southern Pacific System.

The maintenance of way forces may be organized in three ways with relation to the general organization:

1. As a separate department.
2. As a branch of the general engineering department.
3. As a division of the operating department.

The first method is used only on large railway systems, while on small railways the second is preferable to the third. The first method is illustrated in Figs. 3 and 4. Figure 3 gives the departmental maintenance of way organization of the New York Central and Husdon River Railroad, and Fig. 4 gives the divisional maintenance organization of the Union Pacific and Southern Pacific.

Discipline is administered in the maintenance department by a reprimand, suspension, or both. A record of each man's previous services, even down to the track laborer, should be made when he enters the service and a record kept afterward of his services to the company. For minor offenses a personal reprimand given with the understanding that it will be entered in the man's record, will produce the best results with most men. The severity of any sentence, as well as promotions, should largely be based on a man's previous record. That organization which recognizes its old and faithful employees in the way of promotions when vacancies occur, will always have more loyal and efficient employees.

15. General Rules.—The general rules recommended by the American Railway Engineering Association for the government of all employees of the maintenance of way department are as follows:

1. To enter or remain in the service is an assurance of willingness to obey the rules.
2. The service demands the faithful, intelligent and courteous discharge of duty.
3. Obedience to the rules is essential to the safety of passengers and employees, and to the protection of property.
4. Employees must exercise care and watchfulness to prevent injury to themselves, other employees, and the public, and to prevent damage to property. In case of doubt they must take the safe course. They must know that all tools and appliances are in safe condition before using. They must move away from tracks upon approach and during passage of trains, and, so far as practicable, prevent the public from walking on tracks or otherwise trespassing on the right-of-way. They must familiarize themselves with the safety regulations of the road.
5. Employees must do all in their power to prevent accidents, even though in so doing they occasionally perform the duties of others.
6. Cooperation is required between all employees whose work or duties may be jointly affected.
7. Anything that interferes with the safe passage of trains at full speed is an obstruction.
8. Employees in accepting employment assume its risks.
9. To obtain promotion, capacity must be shown for greater responsibility.
10. Employees must not absent themselves from duty, exchange duties with others or engage substitutes.
11. Employees must conduct themselves properly at all times. They will be courteous to fellow employees and patrons of the road.
12. The use of intoxicants by employees while on duty is prohibited. Their use, or the frequenting of places where they are sold, is sufficient cause for dismissal.
13. Employees subject to emergency call shall notify their immediate superior officer and the Division Superintendent of any change in address, whether temporary or permanent.

16. Duties of the Individual.—In a departmental organization, such as that of the New York Central Lines, **staff-assistants** report to and receive instructions from the Chief Engineer.

There are usually certain **general forces**, such as the Mechanical Foreman, Tie- and Timber-inspector and Landscape Gardener, who report to the Chief Engineer and also cooperate with Division Engineers and officials of the operating department.

The **Division Engineer** reports to and receives instructions from the Chief Engineer or Engineer of Maintenance of Way in a departmental organization and to the Division Superintendent in a divisional organization. He has charge of construction, renewal and maintenance of all track, bridges, buildings and other structures on his division, except such works of betterment as are in charge of the Chief Engineer. He must see that all work is done according to the standards furnished by the chief engineer's office. He must make frequent inspection trips over the division and is required to visit, investigate and report on all serious wrecks. He is often required to recommend the amount of insurance to be placed on all property and to see that all wire, pipe or other crossings of the company's property, and spur and side-tracks, are covered by an agreement protecting the company. It has been said that part of the early training of the Division Engineer should be to go without sleep for long periods.

The **Assistant Engineer** reports to the Division Engineer. He is generally held responsible for the keeping of all plans and records up to date, and the furnishing of lines and levels for all engineering work on the division, when asked for by the various supervisors. He is assisted by the necessary draughtsmen, instrumentmen, rodmen, chainmen, etc.

The **Supervisor of Bridges and Buildings,** otherwise termed Supervisor of Structures, Bridge- and Building-master, or General Foreman of Bridges and Buildings, in most cases reports to the Division Engineer, though on the Norfolk and Western and the Frisco Lines the General Foreman of B. and B. reports to the Division Superintendent, as does also the roadmaster. He has direct charge of the maintenance of bridges, trestles, culverts, turntables, abutments, retaining walls, tunnels, docks, buildings, scales, water and fuel stations, etc. He must make a personal inspection, generally in company with the Division Engineer, of all structures during the months of March or April and September or October, and immediately thereafter report, through the Division Engineer to the Chief Engineer, all structures of every description requiring renewal during the next 6 months. He has reporting to him Bridge- and Building-foremen, Bridge-inspectors, Snow-shed- and Bridge-watchmen, Masonry-foremen, and Foremen of Painters.

The **Supervisor of Track** or **Roadmaster,** usually reports to the Division Engineer. He is responsible for the maintenance of the roadbed, track, fences, right-of-way and station-grounds. He must be constantly on the road, at least once each month should examine all cuts, side-hill fills, tunnels, etc., as to their stability; should ride over his subdivision once a week on the engine of the fastest train; must test all track-gages and -levels in service at least every 3 months; and once every

2 months, in company with the Supervisor of Signals, should inspect all interlocked switches. He has charge of snow-plows and work-trains and has reporting to him section-foremen, extra gang foremen and work-train conductors. In order not to obstruct traffic unnecessarily he should keep a close watch on all "slow orders," and see that they are promptly canceled when the work requiring them is completed. The recommended rules of the American Railway Engineering Association, governing Track-supervisors are as follows:

1. Track-supervisors shall report to and receive instructions from the *Division Engineer.*[1]

2. They shall be responsible for the safe condition and proper maintenance of track, roadway, right-of-way, station-grounds and driveways, and must inform themselves of the condition of structures. They must make temporary repairs of such defects as may endanger or delay the movement of trains, and promptly report defective conditions to the *Division Engineer.*

3. They must make frequent inspections of track, roadway, right-of-way, station-grounds and driveways, and have necessary repairs made as promptly as conditions require.

4. They shall, as necessary, employ men for carrying out the duties for which they are responsible.

5. They must know that foremen are familiar with the operating rules in regard to train signals and flagging, and that they fully understand and comply with them.

6. They must, in case of obstruction or damage to track or roadbed, proceed to the place with the forces at their command and do all in their power to promptly clear and repair the track.

7. They shall investigate and report on Form No. ..... accidents which may be attributable to defects in, or result in damage to, track, roadbed or structures.

8. They shall conform to the prescribed standards, plans and specifications in the execution of work under their charge.

9. They must know that foremen are supplied with tools and materials necessary for the efficient performance of their duties, and see that these are properly used and cared for.

10. They must not, except by proper authority, permit experimental trials of appliances or devices, nor give out information of the results of any tried.

11. They shall keep themselves informed in regard to all work performed in their districts by contractors, or others who do not come under their charge, and see that nothing is done by them that will interfere with the safety of track or the movement of trains.

12. They shall have immediate supervision of work-train service for the maintenance of track and employ such service only when authorized by the *Division Engineer.*

13. They must know that foremen are provided with the rules, circulars, forms, special instructions and safety regulations pertaining to their duties, and that they fully understand and comply with them.

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[1] In these and other rules of the American Railway Engineering Association given in this article the words in italics have been inserted by the author.

14. They shall see that the vicinity of all bridges and trestles is clear of all combustible matter, and that bridge seats, tops of piers and other readily accessible portions of bridges and trestles are clear of cinders and dirt and that water-barrels are full of water.

15. They shall see that waterways and the approaches and outlets thereto are free from obstructions.

16. They shall see that no encroachment upon, or occupancy of any portion of the Company's buildings, right-of-way or station-grounds is permitted, except by proper authority.

17. Any action proposed by State, County, Township, Municipal or other authority, which will in any way affect the Company, shall be reported immediately to the *Division Engineer.*

The **Section-foreman** has charge of the actual work of track maintenance, and reports to the Roadmaster. He alone is directly responsible for the efficiency of the work done on the track. He should be capable of outlining the season's work in advance, and should follow his program in carrying out the work. As a part of his duties he must make daily inspection of all track on the section, must see that all waterways are kept open, fences repaired, farm-crossing gates closed, cattle-guards repaired, switches free from snow and ice, and that rail bond-wires are not interfered with. Track-walkers, Track-watchmen and Crossing-watchmen generally report to the section-foreman.

Though near the bottom of the organization, the section-foreman holds a responsible position and is an important unit in the organization. Besides his duties of track maintenance he should endeavor to get on friendly terms with the farmers living adjacent to his section and should show them that he is doing all in his power to protect their property as well as that of the railway. If this attitude is carried out, after a time the farmer will commence to change his views toward the railway and when accidents do occur he will not try to blame it all on the railway, no matter who is at fault. The best section-foreman is an old resident from the vicinity of his section. In any case, he must be honest, industrious, and sober, and should be paid wages high enough to insure his remaining permanently with the company. Excellent results have been obtained on several railways by occasionally calling together all the foremen on the division and instructing them in how best to serve the company's interests. The following are the recommended rules of the American Railway Engineering Association, for the government of section-foremen:

1. Track-foremen shall report to and receive instructions from the *Track-supervisor.*

2. Unless otherwise directed, they shall be responsible for the proper inspection and safe condition of the track and roadway under their charge, and shall do no work thereon that will interfere with the safe passage of trains, except under proper protection.

3. They must go over their sections, or send a reliable man, with suitable tools, at least once a day to make a thorough inspection, to see that the track, highway crossings, signals, culverts, bridges, fences, telegraph lines, etc., are in safe condition.

4. They shall employ men as the *Track-supervisor* directs. They must treat employees with consideration, and see that they properly perform their duties. They must discharge men who are incompetent or neglect their duties, but in no case shall they discharge men without cause. They must keep the required records of the time of their men and of the materials used.

5. They must each have a copy of the current time-table, and be thoroughly familiar with the rules and regulations therein, and with the time of trains over their sections. They must carefully observe signals displayed by all trains, and assure themselves before obstructing track that all trains and sections due have passed. No notice will be given of extra trains, and employees must protect themselves as prescribed by the Rules. Foremen must provide themselves with reliable watches, and, when possible, verify time daily with standard clock or with the watches of other employees who are required to have standard time.

6. If, in the judgment of the Track-foreman, the track or any bridge or culvert is not safe, he must at once put out the proper signals to warn approaching trains, notify the proper officers of its condition, and do all in his power to make necessary repairs.

7. Track-foremen must, in case of accident, promptly render all assistance in their power, whether the accident occurs on their own or adjacent sections. They shall investigate and report on Form No. ..... all accidents occurring on their sections, which may be attributable to, or result in damage to, track, roadbed or structures.

8. They shall conform to the prescribed standards, plans and specifications in the execution of work under their charge.

9. They shall be responsible for the proper care and use of tools and materials necessary for the efficient performance of their duties, and shall make requisition to the *Track-supervisor* from time to time as additional supply becomes necessary.

10. They must not, except by proper authority, permit experimental trials of appliances or devices, nor give out information of the results of any trial.

11. They shall keep themselves informed in regard to all work performed on their sections by contractors, or others who do not come under their charge, and see that nothing is done by them that will interfere with the safety of the track or the movement of trains.

12. They must limit the use of hand-cars to the service of the Company, and must not, except by proper authority, permit anyone except employees of the Company, engaged in the performance of duty, to ride thereon. They must not permit, except by proper authority, the running of hand- or velocipede-cars belonging to private parties over the tracks of the Company.

13. During heavy storms, whether by day or night, whereby the track or any portion of the Company's property becomes liable to damage, foremen and trackmen must be on duty; and at such times they must go over their sections to make sure that the track is safe, taking danger signals with them.

14. They must keep the vicinity of all buildings, bridges and trestles cleared of all combustible matter, such as chips, bark, dry grass, etc. They must keep

bridge seats, tops of piers, and all other readily accessible portions of bridges and trestles cleared of cinders and dirt. Where water-barrels are furnished, they must keep them filled with water.

15. They must keep a careful lookout for fires along the track, and prevent, if possible, the destruction of fences, wood or other material, and the spread of fires into adjoining fields. They must not permit fires to be started unless they have sufficient force to keep them under control.

16. They must use constant care to see that waterways and the approaches and outlets thereto are kept free from brush, driftwood and other obstructions.

17. They must keep all interlocking pipe lines and trunking free from grass and weeds, and all switches, frogs and movable parts of interlocking plants free from snow, ice and other obstructions. They must give special attention to drainage through interlocking plants and where track circuits are used.

18. They must not permit encroachment upon, or occupancy of, any portion of the Company's buildings, right-of-way, or station-grounds, except by proper authority.

19. Any action proposed by State, County, Township, Municipal or other authority, which will in any way affect the Company, shall be reported immediately to the *Track-supervisor.*

The average **Track-laborer** is not a high-class workman, and is generally a foreigner. Section-crews are usually composed of Teutons, Poles, Slavs, Bulgarians, Greeks or Italians, in the East; Greeks, Japanese, Mexicans or Hindus, in the West, and negroes, in the South. Teutons, Bulgarians and Poles make the best foreign track-laborers. Italians are quarrelsome and are not as strong physically as the Greeks. Japanese are quick to learn and are easily handled but are small of stature. Mexicans are strong enough but lack energy. The Hindu is a newcomer and has not proved efficient so far. In the South the negro makes by far the best section-hand, but must be controlled with severity. Negroes work best when one of their number acts as a pace-maker, all others working in unison with him. On Western roads all laborers are employed through labor agencies. This largely accounts for the poor class of track labor to be found there. The results of securing labor in this way are about the same as if the railway allowed an outsider to act as its purchasing agent, the agent receiving a commission from the seller and not from the railway. The extra gang is often recruited from floating labor, the worst class of all.

17. Organization of the Section Forces.—System is essential in maintenance work in order to secure good track at a minimum cost. The expenses for track maintenance are about three times as great as for maintenance of structures. The old system where the section-foreman would take the gang out on the hand-car in the morning, stop here to fix a piece of fence, there to spike down a loose crossing plank, etc., and hunt low joints the rest of the day, will never produce perfect track.

The territory covered by a railway is divided into districts or divisions each of which is further subdivided and each subdivision placed in charge of a roadmaster or supervisor of track. Each subdivision is in turn subdivided into sections. The section-foreman is in charge of the section and is assigned a force of men varying in number according to the location and length of the section, density of traffic, equipment of track, season of the year, etc. The length of section is often fixed arbitrarily. The proper way, however, is to determine an average unit of one man's work by carefully observing gangs at work; then, by observing the time different gangs require to do different kinds of work, fix the length of section on a basis of equivalent mileage. The following equivalents have been used with excellent results on the New York Central:

Two miles of siding = 1 mile of main track.
Fifteen turnouts = 1 mile of main track.
One crossing frog = one turnout.
One single slip-switch = three turnouts.
One double slip-switch = four turnouts.

On most railways the winter forces consist of from 0.3 to 0.5 of a man per equivalent mile and the summer forces from 0.8 of a man to 1 man per equivalent mile, and it is usual to have each gang look after from 5 to 8 miles of track.

The ordinary wages paid section-laborers are not enough to attract reliable men. If the management could be persuaded to increase the wages of section-hands an actual decrease in cost of maintenance work would result by securing more competent men. The winter force is made up of but two or three men and it often happens that these men can get better jobs when the spring comes. In such a case the important unit of the maintenance of way organization starts out on the season's work with all new men. Even if the winter force remains, when the size of the force is increased to the summer basis, from 50 to 75 per cent. of the men are new. By reserving for the winter all work that can be done economically at that season, the size of the winter force could be increased, a better nucleus formed for the summer force and the size of the summer force decreased in proportion to the increase in the winter force. By increasing the wages according to length of service a more permanent organization undoubtedly would be obtained.

The headquarters of the section should preferably be at a small town, but in any case at a telegraph station. In thickly settled country the men often live at home, but in most cases it is necessary for the railway to provide a section-house, which, with grounds and equipment, costs from $600 to $5000, probably averaging about $2000. The tool equipment of the gang costs from $50 to $200. Considering taxes, interest on the investment, insurance and superintendence, the overhead charge per gang is from $500 to $1200 per year on an investment of from $650 to $5200. By increasing the size of gang to 12 or 15 men and placing them in charge of about 15 miles of track one section-house would take the place of two and the overhead charge would be substantially reduced. It is easier to keep an organization of 12 to 15 men and to develop team-work within the gang than where there are but 4 to 8 men in the gang.

18. Unusual Track-force Organization on the Union Pacific.—A few years ago the Union Pacific reorganized the maintenance of way work on the western district of the Nebraska division, consisting of 95 miles of double-track main line and 65 miles of single-track branch lines, in charge of a roadmaster and assistant roadmaster. In the new organization the first section of the main line consisted of 2½ miles of double-track line and a yard at the junction of the main and branch lines. The remainder of the main line was divided into 10 sections each 9 or 9½ miles in length and having 18 or 19 miles of track. On each of these sections there was a section-foreman at $75 per month, an assistant foreman at $65, 12 to 15 laborers during the summer and 5 to 7 laborers during the winter. The equipment of each section included a gasoline section motor-car and push-car trailer, capable of transporting 15 to 20 men with their full tool equipment. Each foreman was provided with a hand-power velocipede for making track and signal inspection. The branch line was divided into three 16-mile sections and one 17-mile section. The section force consisted of a foreman and 6 or 8 men in summer, and the foreman and 1 man in the winter. The results of this organization were far better than formerly with eight 8-mile sections. The signal work, formerly in charge of a signal supervisor, assistant signal supervisor, and one signal maintainer (at $75 per month) for each 13½ miles of track, was placed under the supervision of the roadmaster, and each section-foreman was made responsible for both track and signals on his territory. Each morning the foreman went out on the motor-car with the section-crew while the assistant foreman went over the section on the velocipede, inspecting track and signals, and making all minor repairs necessary. A hand-velocipede was used for the inspection because previous experience seemed to indicate that a thorough inspection of track conditions and signal apparatus could not be made by the use of motor-cars.

On the old separate organization the cost of maintenance per signal was $2.39 per month, while with the consolidated organization the cost was $1.88 per month. It was estimated that the combined organization would effect a net monthly saving of $258 on the double-track main line. The salaries under the new organization were 1 roadmaster at $140 per month, 1 assistant roadmaster at $110 per month, 11 foremen at $75 per month, and 11 assistant foremen at $65 per month.

19. The Extra Gang.—It is the practice to renew ballast, relay rails, clean ditches, etc., with extra or floating gangs. The extra gang is constantly on the move and the men are paid for the time they are being transported from place to place; hence the efficiency of the extra gang is low, probably not much above 25 per cent. The size of the gang is from 15 to 40 men. Without excellent organization more than 40 men cannot work efficiently because of interference and lack of proper supervision. Two foremen are necessary for gangs of more than 25 men and each foreman should have an assistant. Where the work to be done is concentrated on one or two sections the size of the regular section-gang may be temporarily increased to do the work, instead of supplying the extra gang, or two section-gangs may be combined temporarily. If the work extends over considerable territory the extra gang is more satisfactory. In the South several railways carry floating gangs throughout the year.

20. Special Rules of the Maintenance of Way Department.—In addition to the general rules of the maintenance of way department for the government of employees and the execution of work, each railway has certain rules which the track forces must obey in order to protect traffic while work is being done on the track. The following abstract of the rules in this respect of the Frisco Lines is typical:

(*a*) Foremen must at all times be provided with and carry with them flags and lamps of the proper color, torpedoes ready for immediate use when required, and a supply of printed forms as per rule (*b*).

(*b*) When sending out flagmen, the foreman will give each flagman a sufficient supply of printed forms which have been properly filled out and signed by the foreman personally, showing the date, kind of work being done, and exact location of work, as follows:

Form No.........

SAFETY FIRST

..............19......

ENGINEMEN:—

You are flagged on account of..

....

at Mile-post .....plus......poles, to Mile-post............., plus...... poles.

Do not pass that location until you get a signal from me to do so, and then run not to exceed......miles per hour over it.

....

Foreman.

The flagman will hand one of these signed forms to the engineman of each train flagged as per rule (*c*). Enginemen are instructed to throw off to the foreman the form so delivered, as an indication to the foreman that his flagman has carried out his instructions.

(*c*) In case of impassable or unsafe track, flagging is the first duty. When track is impassable or unsafe to a degree that it is essential that trains come to a full stop, or pass at a greatly reduced speed, a reliable flagman must be sent in each direction with proper signals and appliances. At a point of sufficient distance from obstruction to insure full protection, and in no case less than one-half mile, he must place one torpedo on the right-hand rail facing the point to be protected. He must then go five poles farther and place two torpedoes on rail (two rail lengths apart) on right-hand rail facing point to be protected. He must then return to a point near where first torpedo was placed on rail, but always selecting a location where he can be plainly seen from an approaching train, and with a red flag by day and a red light by night, stop all trains and hand each engineman one of the printed forms properly filled out, as per rule (*b*), and, when necessary, explain more fully the reason for flagging. When each train thus flagged proceeds, he must immediately replace torpedoes and take location as in first instance, continuing the protection until notified by his foreman in person, or by a written notice from his foreman, to return. When returning, the one torpedo nearest the point protected must be taken up.

(*d*) Should flagmen hear or see a train approaching before they reach the required distance, they must immediately place one torpedo on right-hand rail facing point to be protected and proceed rapidly in direction of approaching train, giving "stop" signal.

(*e*) On a heavy descending grade, or where other conditions make it necessary, foremen must instruct flagmen to go a greater distance than otherwise, safety being the first consideration.

(*f*) Torpedoes must not be placed near stations, street or road crossings, or near where workmen are engaged, or where persons are liable to be injured by them, and torpedoes exploded or damaged by hand-cars must be replaced. No one should be within less than three rail lengths of a torpedo when exploded, on account of the danger from flying fragments.

(*g*) Foremen must make provision for relieving flagmen who have been on duty an unusually long time, and must anticipate in advance and provide them with night signals in ample time before such signals will be required.

(*h*) Flagmen must be cautioned not to leave their points of duty under any circumstances until recalled, nor to sit while thus engaged, as they are liable to fall asleep, and accidents may result.

(*i*) When temporary conditions necessitate only a slight reduction from schedule speed, a telegraphic slow order shall be put out to all trains at once, the foreman to receive a copy of such train order. Foreman will place yellow flag or lamp on the engineer's side of track, in each direction, a sufficient distance from the point where reduced speed is necessary to afford full protection and in no case less than one-half mile from such place, and green flag or lamp shall be placed on engineer's side of track, in each direction, to indicate the beginning of the place over which reduced speed must be observed. Until foreman receives copy of slow order to trains, he must see that flags or lamps are in position, and after receiving such order he must use reasonable precaution to see that flags and lamps are maintained during the period that the slow order is required.

(*j*) When track is protected, either by flagmen or slow signals, foreman in charge must listen and watch attentively for approaching trains, and when such trains come into view give such signals as the conditions and rules require, standing apart and slightly to one side of his men, giving signals clearly and plainly so that under no circumstances can such signals be misunderstood.

(*k*) Slow signals must not be relied upon where flagmen should be sent out, and must be taken in as soon as conditions warrant.

(*l*) In the use of danger or slow signals on double track, each track must be considered as a single-track railroad upon which trains are likely to be run in either direction at any time.

(*m*) Two track-gangs, or a bridge- and track-gang, must not work within flag limits of each other when possible to avoid it. When it is necessary to do so, a full understanding must be had by both foremen, and their flagmen instructed accordingly.

(*n*) At all points where speed is restricted by time-card order or 31 order, yellow flags or lamps shall be provided as per rule (*i*) if the obstruction is temporary. If the slow speed is likely to be maintained indefinitely a standard permanent slow sign should be placed and provided with a yellow lamp at night.

(*o*) Any disregard of either danger or slow signals, or excessive speed over bad track, must be reported at once to the Roadmaster, giving engine number.

(*p*) When track is to be obstructed within the limits of automatic block territory, the foreman in charge will give signal maintainer at least 24 hours' notice previous to doing any work that will affect the working of signals, if possible. A flagman must be sent out in each direction to the farthest signal which is held at "stop" as a result of this work, who will stop all trains and advise engineman the mile-post and telegraph-pole location of the obstruction. The engineman on being advised as to the reason the automatic block-signal is at "stop" will proceed without sending a flagman in advance, at such speed as will permit stopping the train short of the obstruction. Track must be left in safe condition for traffic until flagmen are out and signal maintainer has set automatic signals at "stop."

21. "Safety First" among Maintenance of Way Employees.—Many dangerous methods are in use by trackmen in performing construction and repair work and in handling tools and materials. It is the duty of every employee to exercise great care to avoid injury to himself, to other employees, and to patrons of the railway, but the men actually performing the work soon become indifferent to risks and hence continue the dangerous practices. Every supervisor of track, structures, and signals should constantly be on the watch for practices of this kind. The following are some of the precautions which should be taken to guard against accident. Foremen must see that all men working on or near the track are warned of the approach of trains. Extra precautions must be taken if approaching train cannot be seen because of fog, standing cars, curves, etc. An endeavor should be made to secure the enactment of legislation making trespassing on the right-of-way illegal and where such legislation exists section-foremen should see that it is enforced. Workmen standing by the side of the track as a train passes should be taught to scrutinize the passing train for any broken, loose, or dragging parts or other dangerous condition. Each workman should see that the tools he uses are in proper condition. When passing through long tunnels trackmen should carry lanterns. Employees whose duties require them to stand or walk on the track, where there are two or more tracks, should face against the current of traffic. Tongs should be used for handling rails, and a competent man should be at each end of the rail and the rest of the gang should pay attention to them. Track-jacks should be handled carefully to avoid accidental tripping. Jumping on and off moving trains, cars, motor-cars, hand-cars, and push-cars; crawling under cars; passing between the ends of cars standing close together; running hand- and push-cars or motor-cars over interlocked switches without permission from the towerman; leaving tools on or near the track; applying brakes on hand- or motor-cars without first warning the men on the car; standing close to the track when a train is passing; and riding or working near a ballast-plow or near the cable to the plow when unloading material—all are dangerous practices and should not be allowed.

In case of personal injury, loss of life, or damage to property section-foremen must, as soon as possible, telegraph or report to the division engineer and the division superintendent. If the breaking of any appliances contributed to the accident, the broken parts should be carefully inspected, labeled, and preserved. In case of personal injury, first-aid measures should be applied and proper medical attention secured as soon as possible. In the case of death all local laws governing the removal of the body must be complied with.

CHAPTER III

ROADWAY

22. Definitions.—The following definitions relating to roadway are given by the American Railway Engineering Association:

1. Right-of-way.—The land or water rights necessary for the roadbed and its accessories.

2. Roadway.—That part of the right-of-way of a railway prepared to receive the track. (During construction the roadway is often referred to as the grade.)

3. Roadbed.—The finished surface of the roadway upon which the track and ballast rest.

4. Alignment.—The horizontal location of a railway with reference to curves and tangents.

5. Grade-line.—The line on the profile representing the tops of embankments and bottoms of cuts ready to receive the ballast.

6. Gradient.—The rate of inclination of the grade-line from the horizontal.

7. Berm.—The space left between the top of a slope and any other excavation; also a horizontal space introduced in a slope.

8. Subgrade.—The tops of embankments and the bottoms of cuttings ready to receive the ballast.

9. Tamped.—Packed down by light blows.

10. Center Stakes.—Stakes indicating the center line.

11. Finishing Stakes.—Final stakes set for the completion of the work.

23. Roadbed.—The width of roadbed at subgrade for single track is from 13 ft. 6 in. to 20 ft. in cut, exclusive of ditches, and from 14 ft. to 24 ft. on embankment. The individual practice of several railways is shown in Table 3.

In most cases the widths for double track are the single-track widths plus the distance between track centers—generally 13 ft. Several railways vary the width of embankments with the height. For instance, the width of single-track roadbed on main track of the Grand Trunk Pacific is 16 ft. for fills up to a height of fill of 16 ft., and 18 ft. for a height greater than 16 ft. On branch lines the width is 15 ft. up to a height of fill of 15 ft., and 17 ft. for a height greater than 15 ft. The Chicago, Milwaukee and St. Paul uses a single-track width of 18 ft. in cuts, 22 ft. on fills up to 20 ft. in height, and 24 ft. on fills over 20 ft. in height; for each of these conditions the width for double track is 13 ft. greater. The width of roadbed for four tracks on the New York Central is 57 ft. in rock cuts and 59 ft. elsewhere. The roadbed is often made wider on curves than on tangents. If the toe of the ballast is carried out to the edge of the roadbed, the width of roadbed must necessarily change with each change in superelevation. This is illustrated by Fig. 22, which shows the ballast section of the Northern Pacific Railway for single track on curves. The changes in width are explained in the last paragraph of Art. 49, page 66. On the Pennsylvania Railroad the four-track width is 60 ft. 2½ in. for cut and 63 ft. 8½ in. for fill.

TABLE 3.—WIDTHS OF ROADBED FOR SINGLE TRACK

Railway	Width of roadbed				Remarks
	Cut		Fill		
	ft.	in.	ft.	in	
A T. & S. F.	16 to 18		16 to 18		
B. & O. and Frisco Lines	20	0	20	0	Class A track.
	16	0	16	0	Class C track.
C. P. R.	14 to 16		14 to 16		
C. R. I. & P.	18 to 20		18 to 20		Width on double track with washed gravel ballast is 27 ft. 7½ in. in cut.
D. L. & W.	14	1½	19	1½	
L. S. & M. S.	22	0	22	0	12 in. of gravel sub-ballast.
N. & W.	16	0	....	....	Rock cuts.
	19	0	19	0	Earth cuts and fills.
P. & R.	13	6	18	6	Width is 27 ft. ½ in. for double track in cut.
P. R. R.	18	5	19	8½	
U. P., S. P., O. S. L.	15	0	16	0	Rock ballast (28 ft. double track).
	16	0	17	0	Gravel, burnt clay, and cinder ballast.
W. & L. E.	17	0	18	0	

The minimum permanent widths of single-track roadbed for Classes A, B and C track, as recommended by the American Railway Engineering Association, are shown in Fig. 5.

Following out the theory upon which the width of an embankment at subgrade is based, the width of roadbed in cut should be made the same as on an embankment. On each side additional width must be provided in a cut for side ditches. The digging of these ditches really leaves the track resting on a low embankment which, if made the same width as the true embankment, will present uniform conditions immediately under the track along the entire line. In any case, the width of the subgrade should be at least 3 ft. greater than the width at toe of ballast. This is not always the case as some railways carry the toe of the ballast entirely out to the edge of roadbed (see Figs. 17 and 22).

The ultimate economy of this is doubtful. With a narrow embankment or where there is little margin between the toe of ballast and edge of roadbed much ballast is lost over the top of the embankment slope.

The different types of roadbed cross-sections may be classified thus: (1) level, (2) two-plane, (3) three-plane, (4) three-plane extended. Typical sections of these are shown in Fig. 6. The section of ditch may be two-plane or three-plane for any of the four classes of roadbed sections. The full lines of the ditches in Fig. 6 indicate the more common ditch section used with that roadbed section. The roadbed of practically every railway in the United States, Canada and Mexico corresponds to some one of these sections. By far the largest number of roads use either section (1) or (2), the two being used on about an equal number of roads. In section (2) the planes intersect in the center of the roadbed for both double and single track. The practice of the Canadian Pacific is an exception to this, since for double track the roadbed is level between track centers and from each track center out to the edge of roadbed the slope is the same as for single track (see Fig. 17). This really becomes a three-plane section. On the C. M. & St. P. the roadbed for double track is made level for 5 ft. at the center. The height of crown varies from 1½ in. for single track on the N. Y. C. & H. R., U. P. and S. P., to 4 in. on the C. P. R., 5 in. on the Lehigh Valley, and 6 in. on the Canadian Northern; and from 2 in. for double track on the N. Y. C. & H. R. to 5 in. on the Lehigh Valley and D. L. & W. For four-track lines the N. Y. C. &. H. R. uses both sections (1) and (2) (see Fig. 13). The

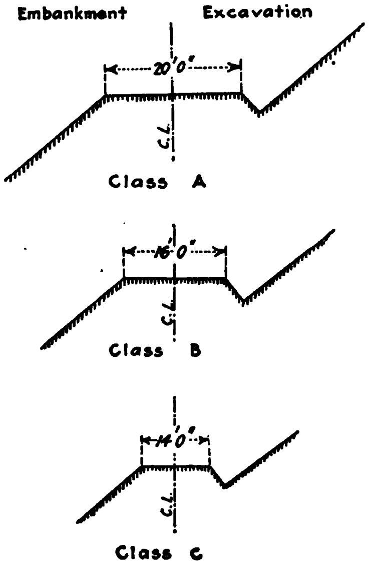


FIG. 5.—Minimum widths for single-track roadbed.

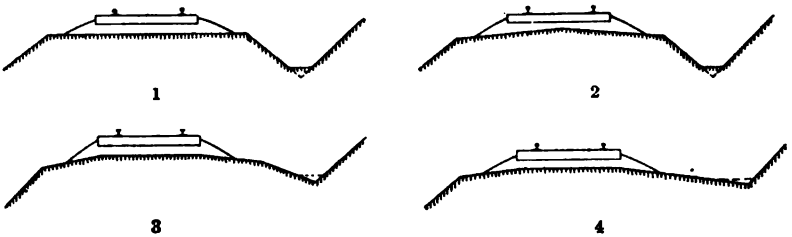


FIG. 6.—Typical roadbed sections.

slopes of the outer planes for sections (3) and (4) vary from ⅛ in. per foot, on the Santa Fe, to 1½ in. per foot, on the Illinois Central. The four-track roadbed of the Pennsylvania Railroad is two-plane, the planes being given a slope of ¼ in. per foot.

The roadbed in tunnels is the invert of the tunnel. It is ordinarily formed in one of two ways, whether single or double track; (*a*) level transversely or (*b*) sloping from each side to the center which is 3 to 6 in. lower than the sides. The Wheeling and Lake Erie R. R. makes the center lower than the sides for single track and excavates an 18- by 18-in. ditch at the center, which is filled with coarse stone to form a French drain. The Baltimore and Ohio R. R. keeps the bottom level and for double track places a tile subdrain at the center and one on each side. Some railways construct an open concrete drain at the center and conduct water to it from the sides by 4- or 6-in. cast-iron pipes laid at intervals in the ballast. The width of roadbed or invert on tangents is from 14 to 16 ft. for single track and 28 to 30 ft. for double track. On curves the width is slightly increased and, because of the tilting of the train due to the superelevation of outer rail, the track is shifted outward from the center so that the upper clearance will remain the same as on tangents.

On curves the roadbed is sometimes inclined transversely to partly correspond to the superelevation of the rail. Nothing is to be gained by such a practice. On the Wheeling and Lake Erie the double-track roadbed is given a pitch of 4 in. each way from the center on tangents. On curves the slope starts from the inner side of curve and continues across the roadbed at the same rate as used on tangents, so that the outer edge of the roadbed is 8 in. above the inner edge. This gives a less depth of ballast under the outer track, since the two tracks are maintained at the same elevation.

There is some difference of opinion as to whether sod should be allowed on the roadbed, but the majority of maintenance engineers agree that the shoulders of the roadbed would be held much better if sodded to within about 1 ft. of the toe of ballast. On the Illinois Central the roadbed is sodded right up to the toe of ballast for both cut and fill sections. Other railways allow sod up to the ballast toe in cuts but keep it from 1 to 3 ft. from the ballast toe on fills. The Atchison, Topeka and Santa Fe, Canadian Pacific, Chicago and Northwestern, Lehigh Valley, Louisville and Nashville, Pennsylvania Lines East, etc., allow no sod on the roadbed.

24. Roadway.—Use has long been made of certain vines and grasses to hold soil and prevent its being eroded by the action of wind and wave. During the past 15 years railways have been experimenting with vegetation to hold the slopes of both cuts and fills, and the planting of some form of vegetation as a protection for slopes is now a standard practice on many railways. Blue grass, rye-grass, red clover, Hungarian brome-grass, western wheat-grass, quack-grass or Bermuda grass, Rhode Island bent, Canadian blue grass, redtop, ground ivy, honeysuckle, wild roses, Irish heath, willows, and alfalfa have been used with varying degrees of success. The primary object is to have the roots of the vegetation hold the material of the slope in place and thus prevent the slope from washing or slipping. The result is a reduction of the work of dressing slopes and cleaning side ditches of cuts. Besides the actual saving in maintenance work, this practice adds greatly to the appearance of the right-of-way. If sod is to be used the character of the material of the slopes may make it necessary to cover the slopes with a thin layer of loam. This varies from 2½ to 6 in. in thickness. A greater depth than 3 in. is liable to cause the sod to slip in very wet weather.

During the work of grade reduction in Toronto, Ont., in 1911–13, the tracks of the Grand Trunk Railway and Canadian Pacific Railway were depressed for about a mile through one section of the city. The maximum depth of the cut was about 35 ft. Where the restricted right-of-way did not necessitate a retaining wall, all slopes were sodded. The sod was cut and rolled by machine. It was laid upward from the bottom of the slope and was placed from ladders resting on the slope. Each piece covered about half a square yard and was fastened to the slope with one wooden peg. The sod cost 24.13 cts. per square yard in place. On the Pennsylvania R. R. the cost of sodding the slopes of a large fill was about 21 cts. per square yard, and included dressing up slopes, applying a 2½-in. layer of loam, and sodding. The same road has obtained very good results by seeding slopes fertilized with street dirt which was obtained free from street-cleaning contractors.

Newly sodded slopes must be regularly watered for sometime afterward. It is often desirable to mow sodded slopes. This costs $9 to $12 per acre for each mowing. The variety of honeysuckle called woodbine will grow from cuttings in almost any except very hard soil. It will cover the ground in 3 years from plants set 5 or 6 ft. apart. Several varieties of rose, such as the Japan rose and Memorial rose, have been used with success in the East. Alfalfa is used because of its hardihood after once started and the success of its long tap root in preventing slipping of the ground on slopes. Three years are required to get a good stand of alfalfa. Willows are frequently planted on the slopes of wet fills and are a great help in holding the slopes. Brome-grass and red clover grow well on north slopes but cannot stand the exposure to the sun on south slopes. Western wheat-grass and Canadian blue grass have been used successfully on both north and south slopes. Quack-grass is a hardy plant, but among some others is objectionable because of its destructive effect upon adjacent crops. In the South the climatic conditions are such that wild vegetation will rapidly cover the slopes of embankments. The conditions existing on the slopes of cuts in all parts of the country ordinarily are such that no vegetation will grow there unless artificially started. In selecting a grass or plant to use for holding a slope it is necessary to consider the exposure to the sun, climatic conditions, material of the slope, and moisture in the slope.

25. Formation of Embankments.—The more solid and compact the roadbed is made, the more impervious it will be and the better it will drain water and support the loads brought upon it by traffic. Unfortunately for the maintenance of way department of new roads, the specifications for settling new fills are very lax. About all that is generally required in the specifications for a railway fill is that the fill shall be made a certain amount higher or wider than the finished height or width of subgrade and be allowed to weather one winter before the track is laid. Where construction is being rushed, the latter requirement is often omitted and the track laid directly on the green fill. Under such a condition it is only to be expected that the first year or two after the railway is put in operation the maintenance of way department will be kept busy trying to bring the track up to grade as fast as it settles. The following is taken from the General Specifications for Grading, of the Lehigh Valley Railroad and follows the recommended specifications of the American Railway Engineering Association.

"Embankments shall be made of such material and built in such manner as directed. Generally, stone and heavy material should form the slopes and finer material be placed in the center of the embankment. . . . . . No frozen, perishable or other unsuitable material will be allowed to enter into their composition."

"When directed, embankments shall be built in horizontal layers of such thickness as may be directed; these layers to be of the full width of the embankment and built to the true slope, and not widened with loose material from the top. The most suitable material must in all cases be reserved for finishing the surface and no large stones will be allowed within a depth of at least 3 ft. below subgrade."

"Embankments shall be carried to such height above subgrade and to such increased width as may be deemed necessary provision for shrinkage, compression and washing."

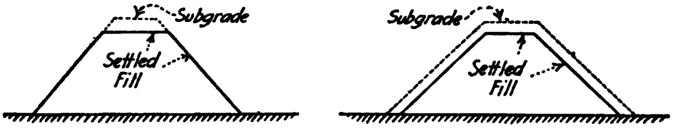
"When an embankment is to be placed on sloping ground the surface shall be deeply plowed and stepped.. . . . ."

"In crossing bogs or swamps of unsound bottom, a special substructure of logs and brushwood may be required, the logs forming this foundation to be not less than 6 in. in diameter at the small end. If necessary, there shall be two or three layers crossing each other at right angle, the logs of each layer being placed close together, with broken joints, and covered closely with brush; the bottom layer shall be placed transversely to the roadway and project at least 5 ft. beyond the slope stakes of the embankment."

If specifications similar to these were adhered to in the construction of all railway-fills much subsequent track trouble would be avoided. The reason for being so lax in the specifications for embankments is to keep the construction cost low, but the heavy expenses afterward for maintenance might justify a greater care in the construction period.

A slight bump of the trucks as the train passes from a fill to a trestle, and a perceptible drop as the train leaves the trestle, is quite often noticeable to a person on the train, even though the person is inexperienced in track conditions. These shocks are the result of two things: first, the elasticity or temporary compressibility of the track on the bridge is less than that of the track on the embankment and second, when the standard of maintenance is not the very highest the fill will have settled slightly leaving the track across the bridge a little higher than on the fill. The experienced trackman can ride over a section of track and, by observing the motions of the train, can understand the general conditions of the track better than by walking over it.

In constructing new embankments an allowance should be made for the shrinkage of the new embankment. The allowance may be made in several ways.



Proper Method Improper Method

FIG. 7.—Extra width of settling fills.

The shrinkage of earthwork takes place almost entirely in a vertical direction but there is always some sliding of the material on the shoulders, so in order that the settled fill may be of standard top width, the new fill must be made both extra high and extra wide. The questions to be settled for any fill are, what shall be the extra height and what the extra width for that fill? Since the height changes at different parts of the fill the extra height and top width must also change. The reason for increasing the width of the fill is that after settlement the embankment can be brought up to grade by dumping on the top of it rather than on the slopes, as shown by Fig. 7. The rule used by the Michigan Central is to widen the base of embankment 1 ft. beyond the normal width for each 5 ft. in height of embankment and to build the embankment slightly above subgrade.

The following analytical solution of the settlement problem has been proposed by Prof. J. C. L. Fish, of Leland Stanford Jr. University.[1]

A fill may be built (a) allowing for only a part of the vertical shrinkage with the expectation that it will settle below subgrade; or (*b*) allowing for the full vertical shrinkage so that it will settle just to subgrade; or (*c*) just to subgrade so that it will fall below subgrade the amount of the full vertical shrinkage. In the following solution the fill is assumed to be built on ground that is practically level transversely. The three conditions are shown in Fig. 8, where h = subgrade height, h' = the center height greater than h, h'' = the center height less than h, s = slope ratio of settled fill and s' = slope ratio of new fill.

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[1] Vol. 15, Proceedings, American Railway Engineering Association.

(*a*) If the shoulder of the new fill was at B' the shoulder of the settled fill would be at B'' while for that height of fill the shoulder should be at C'', beyond B''. Therefore, the shoulder of the new fill should be over the point C'', or at C', even if no sliding of the shoulder occurs.

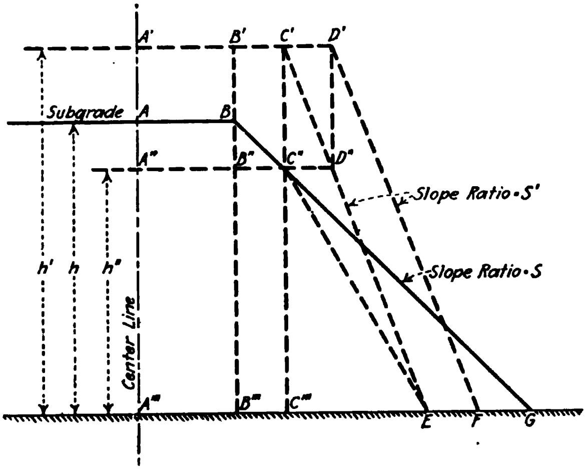

FIG. 8.—Extra height and width for new fills.

With the shoulder of the new fill at C' and a slope ratio of s', the toe of slope would be at E, and if there were no sliding the slope of the settled fill would be $C''E$. However, this slope is too steep and the shoulder at C'' cannot be stable unless the triangle $C''EG$ is filled. To fill this triangle an additional slab $C'D'EF$ must be added to the side of the new fill, and this area when settled must equal the area of the triangle $C''EG$. The area of the slab after settling (considering that settling all takes place in a vertical direction) will be $h'' \times C'D'$.

$$\begin{aligned}
\text{Area of triangle } C''EG &= \tfrac{1}{2}h'' \times EG. \\
h'' \times C'D' &= \tfrac{1}{2}h'' \times EG \\
C'D' &= \tfrac{1}{2}EG \\
&= \tfrac{1}{2}(C'''G - C'''E) \\
&= \tfrac{1}{2}(h''s - h's') \qquad (30a)
\end{aligned}$$

and the total top width to be added to the standard width of the roadbed is $B'D'$.

$$B'D' = B'C' + C'D'$$

$$B'C' = B''C'' = (h - h'')s$$

Therefore, $$B'D' = (h - h'')s + \tfrac{1}{2}(h''s - h's') \qquad (30b)$$

(*b*) For the fill which is built with full shrinkage allowance, $h'' = h$ and $h - h'' = 0$, which reduces Eq. 30*b* to,

$$B'D' = \tfrac{1}{2}(h''s - h's') \qquad (30c)$$

(*c*) For the fill which is built just to subgrade, $h' = h$, and Eq. 30*b* becomes,

$$B'D' = (h - h'')s + \tfrac{1}{2}(h''s - hs') \qquad (30d)$$

In practice the values of h and h' are known and that of s' can easily be found. The values of h'' and s, however, are not so easily determined. These two values depend entirely on the character of the material of which the fill is made and the manner of making the fill, and are subject to some uncertainty. The fixing of their values is a matter of judgment on the part of the engineer. Because of these two necessary assumptions the solution, though sound theoretically, becomes really a guide to the engineer's judgment. The following example will illustrate its application.

Example.—The center height of subgrade for a new fill is 50 ft. The side slopes of the new fill are measured and the material is found to be standing at a slope of 1¼ to 1. From observation of similar material in old fills it is estimated that the slope ratio of the settled fill will be 1½ to 1. The vertical shrinkage is judged to be 10 per cent. and it is desired to build the fill sufficiently high and wide so that the top of the settled fill will be the proper width and height for subgrade. Then, $s' = 1.25{:}1$, $s = 1.5{:}1$, $h'' = h = 0.9h'$, and $h = 50$ ft. $\therefore h' = 55.56$ ft.

From formula 30*c*, $$B'D' = \tfrac{1}{2}(50 \times 1.5 - 55.56 \times 1.25)$$
$$= 2.775 \text{ ft., the additional width at each shoulder.}$$

Therefore, the total extra top width would be 5.55 ft.

26. Embankments across Unstable Ground.—Aside from the stability of the fill itself, the ground upon which it rests is sometimes so unstable that a proper support for the track is difficult to obtain. Such is generally the case in crossing swamps, salt marshes, bogs, quicksand and muskeg. Cases have occurred where the track was laid on what appeared to be firm ground which later settled, showing only a thin crust of solid material over a plastic mass of earth or peat. Some phenomenal cases of track settlement occur from time to time and, as the repairing of track at those places often comes under the supervision of the maintenance of way department, mention will be made of some of the more phenomenal instances.

Many of the railways in certain parts of Canada have had much difficulty in crossing large areas of muskeg.[1] In the construction of the National Transcontinental Railway the line had to be built for many miles over muskeg. The difficulties encountered were enormous. At Barclay, Ont., the Canadian Pacific Railway encountered much trouble from this source and from the amount of material required to get a permanent fill it was estimated that the muskeg was 200 ft. deep.

In some instances the Canadian Pacific has used sawdust in building embankments across soft ground where other material would break through the surface crust of the swamp. The embankment was constructed of sawdust and the top and slopes were covered with earth to protect the sawdust from fire.

The most successful method of carrying a fill across a marsh is to lay a pole or brush mattress on the surface of the marsh as a foundation for the fill, similar to that in the specifications of the Lehigh Valley, given in the preceding article. This practice has doubtless been copied from Holland or Ireland where it has been used for many years for crossing swamps and bogs. In southeastern Virginia, extending partly into North Carolina, lies the Great Dismal Swamp, covering an area of about 300 square miles. All railways reaching Norfolk by rail cross more or less extended arms of the swamp. Across these places the track is placed on a low fill which in most cases rests on a foundation of timber cribbing laid on the surface of the swamp. Almost the entire area of the swamp is covered with from 1 to 7 ft. of water. In some places the passage of a train causes the small vegetation 200 to 300 ft. from the track to shiver and shake from the vibration of the jelly-like mass. The work of maintaining these tracks is excessive.

Several years ago the Southern Pacific Railway revised its line around the north end of Great Salt Lake, Utah, and built the track, partly on fill, directly across the lake, thereby making a saving in distance of 59 miles. This revision is known as the Lucian Cut-off. While building certain sections of the fill, train-load after train-load of rock was dumped into the lake, all of which disappeared without leaving any trace of a fill. After an enormous amount of material had been dumped into the lake at one place, an island appeared in the lake about 500 feet from the place of filling. Before the fill was started the water was 20 to 30 ft. deep at the point where the island appeared. The settling of the embankment caused the bottom of the lake off to one side to bulge upward to such an extent as to protrude above the surface of the water. So much trouble was encountered in the construction of this cut-off that after several millions of dollars had been spent the railroad company seriously considered abandoning the work. For several years after the cut-off was opened for operation a slight settlement continued, making maintenance very expensive.

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[1] Muskeg is the name given to those marshy areas in Canada which consist of rocky basins filled with successive deposits of unstable material, such as leaves, muck and moss, which is incapable of sustaining much weight.

For several years past the same railway has had much trouble in maintaining its tracks across the Suisun Marshes, about 30 miles east of San Francisco. This is a tide-marsh near where the Sacramento and the San Joaquin Rivers empty into an arm of San Francisco Bay. For several miles the railway is built across the marsh. Serious trouble was first encountered soon after the line was double-tracked. There appears to be a fairly firm surface layer, overlying the blue mud of the marsh, which had held up under the single track, but gave way under the added weight of the second track, although most of both tracks were laid on a timber cribbing as a foundation. The settlement is, however, not uniform. For several months there will be little trouble, when suddenly the track will commence to settle and perhaps for months a force of men will have to be kept at work day and night building up the embankment apace with the settlement. The surface layer shears off 10 to 15 ft. from the edge of the track and sinks down under the water. Piling has been tried but without success. The greatest trouble appears to result from the fact that the underlying firm strata lies at an angle with the horizontal, so that in driving the piles they do not penetrate it but are deflected off to the side, and when the solid fill reaches it the bottom of the fill sooner or later commences to slide along the inclined surface and the top of the fill settles accordingly. Piles driven under the track have disappeared in the marsh and afterward reappeared on the surface a quarter of a mile from the track.

During the month of July, 1913, the settlement of this track was so rapid that it was necessary to abandon the operation of it for several days although it is a part of the main transcontinental line, and the diverting of traffic to a roundabout route offers serious problems to the operating department. No permanent solution of the problem has yet been made. A relocation avoiding the marsh would be almost impossible.

These examples are extraordinary and similar ones may never be encountered on many railways but they are mentioned to show that the work of maintenance is not always a matter of replacing decayed ties, redriving spikes, etc., but that the engineering problems to be solved are often among the most difficult of any found in railway engineering.

27. Drainage.—The most important feature of economic maintenance is the proper drainage of the track and entire roadway. The worst enemy of the roadbed is water, and the farther it can be kept away, or the sooner it can be diverted from the roadbed, the better the track will be protected.

Drainage of the track proper is effected by the ballast and crown of the roadbed. The drainage of the roadway is effected by providing (1) side ditches, (2) intercepting ditches, and (3) subdrains. These three kinds of drains are shown in Fig. 9. Side ditches in cuts are absolutely indispensable. They should always extend at least 1 ft. below subgrade. In old wet fills it is sometimes necessary to widen the cut with a steam shovel so that the ditches can be deepened. The cross-section of the ditch must be sufficient to take all water reaching it. The minimum width of the bottom should be 12 in. and in wet climates or in wet cuts a width of 24 in. may be required. Many railways give a slope of 1½ to 1 to the sides of the ditch. A slope as flat as 3 to 1 will better prevent erosion of the sides. Of still more importance than the cross-section is the fall of the ditch. If the slope is too flat the water will not be rapidly carried away and some of it will undoubtedly be absorbed by the roadbed, thus defeating the very object of the ditch. The slope will depend somewhat upon the character of the material of the cut, but in any case it should be steep enough to carry away at once all water reaching it and to give to the water a velocity sufficient to carry away any material washed down from the cut slopes and the roadbed, and thus be self-cleaning. In long cuts an effort should be made at some intermediate point to dispose of the water from both ditches in order to prevent its being carried for long distances in the ditches. It is often possible to do this at little expense by a cross ditch on the low side of the cut, running from the side ditch out to the surface of the ground on the hillside below. If this can be done, the water from the other ditch should be brought across under the track by a wooden box or cast-iron pipe. Where water is carried for long distances in side ditches a certain amount is bound to be absorbed by the adjacent roadbed. In this way water may reach a portion of the roadbed which would otherwise be dry. The ideal condition for draining exists where a summit in the

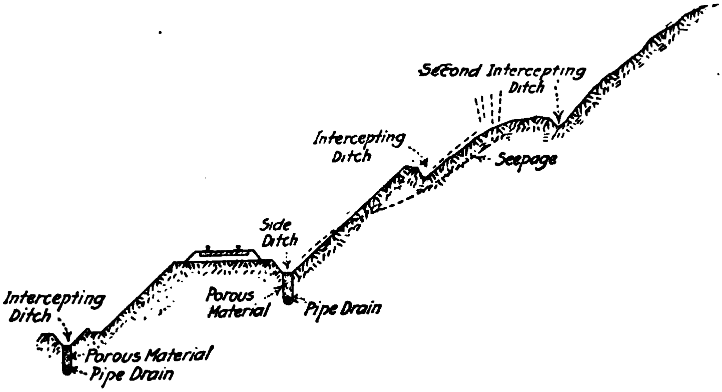

FIG. 9.—Roadway drains.

track profile occurs near the middle of the cut and the track drops away on each side with a gradient of 0.4 per cent. or over. The cut will then drain each way from the center and the bottom of the ditches can be kept at a uniform distance below subgrade. A long cut on a light gradient requires very deep ditches near the lower mouth of the cut. The fall of the ditches should not be less than 4 to 6 in. per 100 ft. The importance of keeping the ditches open at all times is too apparent to require emphasizing. A small stone or slide from the slope above, which could be removed in a few shovelfuls, may, if left, completely clog the ditch.

The upper side of all cuts and the slope above tunnel-portals should always be protected with berm or intercepting ditches. These are almost as important as the side ditches because they prevent water from reaching the roadway. Second and even third ditches farther up the hillside may be necessary. By properly ditching the hillside above the cut much water which would not appear on the ground surface directly above but which would seep out of the face of the cut can be turned aside. Intercepting ditches also must be given a good fall and be kept clean at all times. The flow of water in natural channels, such as ravines intercepted by the cut, should be kept out of the cut if there is any possible means of doing so.[1]

Much attention is now being given to subsurface drainage of troublesome cuts and fills. Where drains of this kind have been used the results have been very gratifying. Subdrains may be of tile or of the so-called French drain type, and a perforated, corrugated, cast-iron pipe has been used with success on the Pennsylvania, Erie, and Queen and Crescent. In the past, porous farm-drain tile was extensively used but experience proves that the advantages claimed for it are not realized. The volume of water admitted through the sides is very little unless the head of water is considerable and in railway drainage the object is to avoid backwater or water under head. Another objection is that the pipe is not so strong as vitrified or glazed pipe, and in time will crumble. Ordinary bell and hub vitrified sewer-pipe is sometimes used but the bell prevents the free entrance of water and eventually will partly clog. Open-joint vitrified and cement pipe give the best results. In soft material these should be laid in a V-shaped wooden trough. Any kind of open-joint pipe admits more water than does the sewer-pipe. After a time French drains become clogged and lose their effectiveness. Cast-iron pipe is considerably more expensive than the other kinds. The sizes of the drain pipes used vary from 4 to 12 in. A minimum size of 6 in. is best as smaller sizes clog very easily. In earth cuts the drains should be laid not less than 3 ft. below subgrade and deeper if possible. Up to a depth of 7 ft., the character of the soil being considered, the deeper the tile is laid the better the roadbed will be drained. Below 7 ft. no advantage is gained. The drain should be placed as near the track as possible, but the distance will generally be limited by the ballast section so that the pipe can seldom be placed less than 7 ft. from the center of a track, and it will generally be from 10 to 12 ft. The pipe should be laid to true line and grade, as for any other kind of drain. The upper end of the pipe run must be sealed. Material excavated from the trench should not be used for back fill. In place of this a porous material such as gravel or cinders should be used. Water from springs should be carried away immediately by a line of tight-joint pipe. Seepage from the slope of a cut, that cannot be prevented by intercepting ditches above the cut, may be intercepted by subdrains laid parallel to the track in the slope of the cut.

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[1] The author once saw the track of the Denver and Rio Grande in the canyon of the Arkansas River above the Royal Gorge, blocked for several hours by a summer rain lasting less than an hour. Large volumes of water poured over the track from ravines on the upper side of the track. In some places the ballast and roadbed were completely washed away, while in other places several cubic yards of sand and gravel were deposited on the track. It would be very expensive, if not impossible, for a road so located as the Denver and Rio Grande through that canyon, to properly dispose of all surface water from ravines above, but the importance of caring for water from such sources is apparent.

Water from the side ditches of cuts must not be allowed to flow out along the toe of the fill, but should be carried free of the fill by run-off ditches constructed along the shoulder of the hill back of the fill. Washes which occur on the slopes of fills a second time in the same place should be back-filled with stone or gravel to prevent a recurrence of the wash.

Many embankments rest on ground having a transverse slope. Where this is the case the base of the fill will become saturated if water from above is allowed to accumulate against the fill. If the ground surface is steeply inclined the wet base may cause the fill to slide. A condition of this kind calls for subdrains. Particularly if the fill foundation is saturated from ground water, deep subdrains with unobstructed outlets are the only remedy.

The unevenness of track on fills is often caused by wet fills. Not infrequently the trouble is more serious than that caused by wet cuts. The foundation may be wet or the fill itself may become saturated from water falling on poorly drained track. Even in track where every ordinary drainage measure is taken, depressions which retain water may form in the surface of the roadbed, both in cut and fill sections. These are called water pockets. They are of two general forms: (1) a U-shaped pocket, with the greatest depth under the center of the track, or (2) V-shaped troughs, with greatest depth directly under each rail, and with the embankment material forced upward in the center of the track. Water pockets in track with deep ballast are usually of the first form. When well-ballasted track has been long in service, a large volume of ballast will have been worked into the roadbed. This may extend to a depth of 4 or 5 ft. under the center of the track, while beyond the ends of the ties little or no ballast will have entered the roadbed. A pocket is thus formed in which a large volume of water will accumulate. The second form of water pocket is more common in thinly ballasted track. The trouble from water pockets in fills can be remedied only by constructing tile or French cross drains at intervals in the fill, placing them about 12 in. below the lowest point of the pocket. Pockets in cuts are more difficult to cure. The only sure remedy is the construction of tile subdrains. If for no other purpose, the roadbed should be given a crown to prevent the formation of pockets.

Small pipe culverts often become clogged by débris or a broken pipe, causing water to stand above the fill. A tile drain through a fill should always be laid in a shallow trench excavated before the fill is placed. The pipe is then held to line and grade by the trench while the fill is being made. Culverts should be of such size as to carry away all water without allowing it to back up above the fill. In a few instances trouble from wet foundations has been reduced by "shooting the fill." Holes are bored through the fill and well into the foundation. These are lightly charged with dynamite and are shot. The blast opens up fissures and cavities in the ground into which water drains from the wet ground under the fill.

All railway troubles due to too much water may be classified as follows: (1) Slides. (2) Washouts. (3) Side-wash from streams.

28. Slides.—Slides may be classified as (1) slips of material on the side of an embankment, away from the roadbed; (2) slips of a portion of the side of a cut toward the roadbed; (3) slides of more or less extended areas of land moving down to a lower level.

Slides of the first class always occur in wet weather, the greatest trouble coming from side-hill sections in clay, as the entire roadbed is likely to give way and slide downhill carrying the track with it. Clay is very hard to drain. It does not absorb water readily but when once it does get saturated it is almost impossible to drain the water out of it.

Water is the cause of nearly every slide of each class and the cure can be found only in proper surface and subsurface drainage. The driving of piles to hold sliding masses of both embankment and fill is sometimes resorted to. At best this is only a temporary expedient. Where slides repeatedly occur, the slope should be flattened by removing material from the slopes of cuts or adding to the slopes of fills. In the latter case retaining walls at the toe of slopes may be necessary if the right-of-way is restricted.

The formation of much of the ground around Puget Sound is clay and the railways in that vicinity have considerable trouble from slides. In the Coast Range Mountains of California much of the soil is of such a character that, when saturated with water, it becomes a plastic mass which really flows instead of slides. The maintenance of way departments of the railways in that State expect trouble from such sources every winter. As a rule, trouble from slides is not foreseen when the line is being located and built, so that the solution of these problems rests with the maintenance of way department. The drainage of a large area of land adjacent to the track frequently is necessary to secure proper drainage of the roadway.

The influence of seepage water on earth movements is illustrated by a condition met by the Canadian Pacific Railway along the Thompson River about 200 miles east of Vancouver, B. C. Before the railway was built some of the terrace lands above the river had been irrigated. After a few years the ground became soaked with seepage water from irrigation and some very bad slides occurred. At one place a piece of land half a mile wide and extending three-quarters of a mile back from the river, covering about 155 acres, dropped vertically at the back in one movement to a depth of over 400 feet. The lower portion was pushed ahead until it came to rest against a bluff on the opposite side of the river, damming the river to a height of 160 ft. and forming a lake 12 miles long. As soon as the river rose above this dam the water soon washed away the obstruction. Five other bad slides occurred within a distance of 6 miles. The ground formation which caused the slides was an inclined strata of clay silt underlying the surface soil and upon which the surface soil slid. This was one case where the condition was known prior to location, but in locating the line it was impossible to avoid crossing the slide. In the case of the largest slide practically all the surface soil was carried away leaving nothing for cultivation so that the irrigation was stopped and the clay soon dried out, causing no further trouble. In the case of the small slides the remaining soil was still plentifully irrigated and since the construction of the track it has been constantly pushed toward the river, sometimes at the rate of 8 ft. per day with an accompanying settlement of 3 or 4 ft. A new roadbed has been built several times, in each instance only eventually to be forced into the river and washed away. On Sept. 4, 1913, several land slides occurred on the British Columbia division of this railway. At one point the track was covered to a depth of 25 ft. and traffic delayed for some time. Boulders as large as 27 cu. yd. fell upon the track. The slides were the result of heavy rains on the two or three preceding days.

On the Kanawha and Michigan Railway along the Great Kanawha River in the mountains of West Virginia much trouble was encountered for several years from slipping of the embankment, and slides coming down upon the track. In almost every case where a bad slide occurred, the hillside above had been cleared of all forest. All of the large slides moved quite slowly, thereby causing no immediate danger. Some of the slides were of such an extent that it was impossible to remove the sliding material, which consisted of mucky clay, varying in depth from 8 to 20 ft., resting on an inclined strata of rock. At one point the slide was successfully checked by driving a double row of piling braced together, as shown in Fig. 10. All timber used was white oak. Above the piling the hillside was given a slope of 1½ to 1. Three years after being driven this piling was still holding the slide satisfactorily. For smaller slides one row of piling was found to be sufficient. At another point on the same railway where the track was on a fill over sliding ground the movement was checked by driving a row of piling on each side of the track and bracing together the piles in each row. The piles were equipped with a steel shoe and were driven to the underlying rock strata. One remedy suggested was to scarify the smooth surface of the inclined underlying rock by putting down holes into the rock and blasting it, thus obtaining a grip on the sliding surface material.

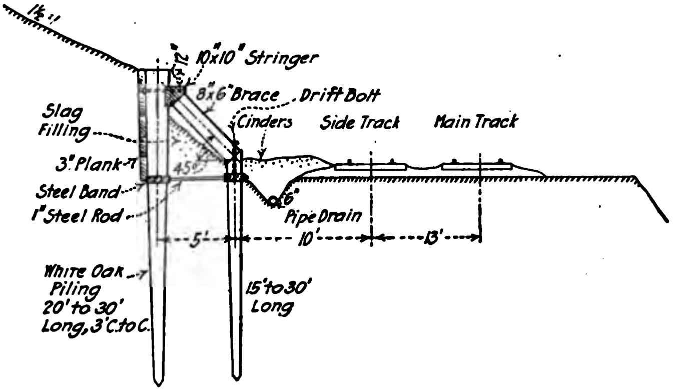


FIG. 10.—Bulkhead for holding slides, Kanawha and Michigan Railway.

29. Washouts.—Washouts are caused by the same agency as slides, that is, uncontrolled water. In the case of washouts, however, the water is from a stream which has overflowed its normal channel. Washouts may be caused by (1) water which scours around the ends of embankments near the stream, (2) water which has accumulated on one side of the embankment and forces its way through the embankment at the weakest point exposed, or (3) water which overtops the embankment and overflows the track.

The first cause may be prevented by protecting the ends of the embankment with riprap of stones of sufficient size to resist the force of the water tending to move them. Riprap placed by hand in rough courses and extending well above the high-water mark is the most efficient.

The second cause itself is generally the result of a blocked drain or culvert, or an opening having an insufficient waterway. Water backs up against the fill until the head is sufficient to force it through a weak or porous spot in the fill. Not infrequently this weak spot will be around the outside diameter of the drain pipe or culvert. If observed in time, a break of this kind may be checked by placing gunny sacks filled with sand in the opening. If a complete washout occurs, the first consideration is to temporarily repair it in the shortest time possible so that the interruption to traffic will be a minimum. This may often be done best by building a cribbing of old ties under the track. Steps must then be taken to permanently repair the washout. In some cases it may be best to build a culvert or trestle where the break occurred, thus providing additional waterway for future floods. Ample openings should be provided at all streams. In determining the size of opening required too much reliance should not be placed on empirical formulas. Where it is possible to do so the actual drainage area should be found and the volume of run-off computed as in sewer work.

In certain parts of the country, particularly along the Mississippi River and its tributaries, the tracks of many railways are subjected to the third cause of washouts during certain months, generally May and June, of almost every year. During these periods an area 5 to 10 miles wide on each side of the river may be flooded. The only reasonably sure prevention of washouts from the third cause is to build a solid rock-faced embankment high enough to place the track above high water. Often this cannot be done. The best precautions then are to heavily riprap both slopes of the embankment and use ballast of large-sized angular broken stone. A swift current may even wash out stone ballast. During the flood it may also be advisable to build a wall of gunny sacks on one side of the track to break the velocity of the water and prevent its erosion of the ballast and embankment.

30. Side-wash along Streams.—Railways built along the banks of alluvial streams sooner or later are troubled by the tendency of the stream to shift its channel. If the stream has a rock bottom the embankment can be protected from side-wash by riprap or by dumping broken stone upon the side of the fill. If no solid bottom exists it may be necessary to protect the embankment by covering the adjacent bank of the stream with a brush mattress held down by a layer of stone. Work of this kind is very expensive. A mattress 40 to 60 ft. wide will cost from $5 to $10 per linear foot of track.

31. The Drifting of Sand.—The lack of water often causes almost as much trouble as an excess of it. In arid sandy districts it is difficult to keep the track free from sand which the wind drifts across it. Or the wind may have an opposite effect and carry away the material of the embankment, which is also sand. It not only causes constant work on the part of the maintenance forces but may stall trains. In addition, the grit works into the moving parts of the machinery and causes excessive wear of wheel-journals and the machinery of the locomotives. The trouble is reduced by sprinkling the roadway with oil, by spreading cinders or gravel or by planting vegetation on the right-of-way. There are several kinds of desert and beach grasses that will grow in practically dry sand. Through the desert sections along the Columbia River the Oregon-Washington Railroad and Navigation Company uses sand-fences very similar in design to ordinary snow-fences. The use of crude oil sprayed over the ground for a distance of from 30 to 50 ft. on each side of the track gives very good results. The oil binds the sand particles together and forms a smooth crust which prevents the sand under it from shifting and causes the sand from beyond, which is blown upon the oiled crust, to glide over and across it and away from the track.

CHAPTER IV

BALLAST

32. Purposes of Ballast.—Ballast is the name given to the material placed upon the roadbed and in which the ties are embedded. The name originated in England where gravel brought there as ballast by ships was used on some railways as a material for holding the ties in place.

Ballast is a very important item in securing good track and economical maintenance. The purposes for which ballast is used are:

(*a*) To drain water away from the ties.
(*b*) To hold the ties in place.
(*c*) To transmit the load from the tie to the roadbed.
(*d*) To distribute this load as evenly as possible over the roadbed.
(*e*) To prevent the heaving of the track from the action of frost.
(*f*) To allow resurfacing and relining track without disturbing the roadbed.
(*g*) To retard the growth of vegetation in the track.

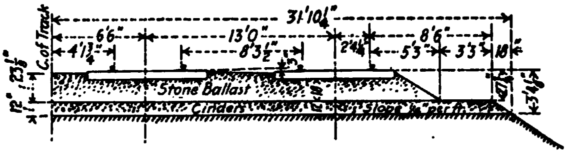
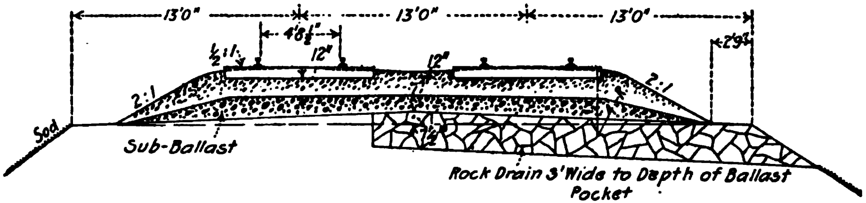


Fig. 11.—Standard 4-track ballast section on fill, P. R. R.

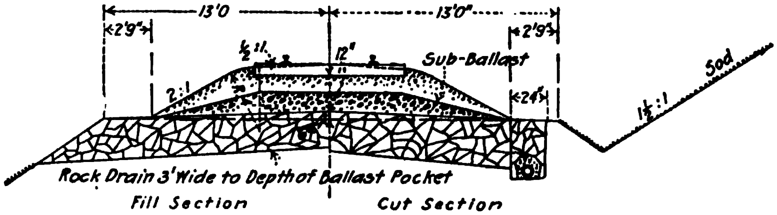
In constructing new track, ballast should not be placed until the roadbed is brought to finished subgrade and should not be used for bringing low embankments up to grade because (*a*) it is too expensive a material to be used in such a way and (*b*) to insure uniform operating conditions the depth of ballast below the tie should be uniform over the entire length of line.

The tendency is for the ballast gradually to work down into the soil of the roadbed and on old track which has been properly kept up to grade it will be found that the depth of ballast is considerably in excess of the standard for that track. This makes a good foundation for the track but is expensive. Several railways use sub-ballast, particularly where the subgrade is wet or of a material difficult to drain. This generally consists of an 8- to 12-in. foundation course of slag, gravel or cinders. On wet roadbed the New York Central Lines use a 12-in. layer of gravel or cinder sub-ballast. In some places the Pennsylvania R. R. uses 24 in. of sub-ballast but the standard depth is 12 in., as shown by the standard 4-track section for embankment, Fig. 11. The ballast and sub-ballast section proposed by the 1914–15 Committee on Ballast of the American Railway Engineering Association, for single and double track, is shown in Fig. 12.

The thinner the layer of ballast the greater is the loss of ballast due to its being worked down into the soil of the roadbed. This loss results from poor drainage and the safe bearing power of the soil being exceeded. Shallow ballast invariably means constant work of resurfacing.



Double Track on Tangent



Single Track on Tangent

FIG. 12.—Proposed ballast sections, Am. Ry. Eng. Assn.

33. Properties of Ballast.—It follows from the purposes for which ballast is used that ideal ballast should possess the following properties:

1. Retain no water.
2. Have a firm grip upon the tie, or offer as much friction to the movement of the tie as possible.
3. Not disintegrate under the action of traffic, tamping, or the elements.
4. Be easily worked and tamped.
5. Be free from dust and not form dust.
6. Not heave from the action of frost.
7. Prevent the growth of vegetation.
8. Be of low cost.

34. Selection of Ballast.—Many different circumstances affect the choice of the material to be used for ballast. The engineer may well know what particular material would make the best ballast but financial considerations may eliminate that material from the list of those available.

Or, the best kind may not be obtainable in that locality and the question then is to find the best provided there by nature and use it. It is practically impossible to obtain a uniform quality of any natural ballast, but in the case of crushed stone or screened gravel, the process of manufacture is under control so that it is possible to produce any quality desired.

The kind of ballast used may have a noticeable effect upon the maintenance cost of the rolling-stock and sometimes, with passenger-traffic, upon the actual volume of traffic. The wear of journals and all exposed moving parts of the machinery is considerably augmented by dusty ballast and on railways especially catering to the traveling public it is more important to avoid dust and dirt by the use of clean ballast than to avoid smoke and cinders by the use of anthracite coal or oil for fuel, or than even to eliminate the irregularities of track which cause rough riding. By a dusty ballast is meant one from which clouds of dust rise and envelop and follow the train as it passes along the track. Where the ballast is dusty the dust nuisance may be very greatly reduced by sprinkling the track with crude oil.

A ballast that does not drain well will hold moisture around the tie and hasten the failure of the tie from decay. Irrespective of drainage, the kind of ballast may affect the life of the tie through mechanical wear. A tie suffers from a certain amount of mechanical wear on its sides and bottom from the action of the ballast. The direct action of the ballast is, however, never a cause of failure of the tie. The real damage results from the action of the tamping tool striking the bottome edges of the tie. These edges may ultimately become so rounded from frequent tamping that little or no flat bearing-surface remains. The tie will then rock in the ballast and difficulty will be had in keeping it up to surface. Although otherwise sound, such a tie will generally be removed from the track. Frequent tamping, resulting in a tie failure of this kind, is usually the result of a soft roadbed, so that the failure is largely due to poor drainage. The damage from tamping is more pronounced in stone and coarse slag ballast than in gravel, cinders, and other soft or finely granulated materials.

Rail or tie-plate cutting of the tie is much more rapid where the ballast contains grit, as does gravel, granulated slag, chats, cinders, disintegrated granite, sand, etc. The grit works in between the rail or tie-plate and the tie and increases the grinding away of the wood. If the tie-plate is of such a design that it can be firmly seated to the tie this trouble largely disappears.

It may frequently happen that in the long run a more expensive ballast hauled from a distance will give greater economy than a cheaper but inferior ballast obtainable near by. From the point of ultimate economy, that ballast is the cheapest which, for a unit length of track and a given volume of traffic, section of rail and kind of tie, makes the annual interest on first cost of ballast, plus yearly cost of tie-renewals, plus yearly cost of replenishing ballast, lining and surfacing, a minimum.

35. Materials Used for Ballast.—Ballast Sections.—The materials, in order of desirability, which are used for ballast are the following:

1. Broken stone.
2. Coarse slag.
3. Screened and washed gravel.
4. Chats, granulated slag and disintegrated granite.
5. Burnt clay.
6. Bank or river gravel.
7. Cinders.
8. Chert and cementing gravel.
9. Sand.
10. Shells.
11. Earth.

The form of ballast section depends on four things: (1) the kind of ballast, (2) the kind of material composing the subgrade, (3) the volume of traffic and (4) climatic conditions. Heavy traffic and an unstable roadbed require a deep ballast. A light ballast under heavy traffic must be deep and shouldered out well beyond the ends of the ties. From all available data, it appears that, using a 7- by 9-in. by 8½-ft. tie spaced 24 to 25.5 in. center to center, a depth of 24 in. of stone ballast is necessary to produce an equal distribution of the pressure over the subgrade. An 8- to 12-in. layer of cinder sub-ballast and 16 to 12 in. of stone will produce about the same results.

Where there is a track circuit the ballast must be kept away from the rail. In a material that does not drain well the ends of the ties should be entirely free from ballast to allow water to escape quickly from under the ties.

Ballast sections can be classified in two ways: (*a*) as to the form of top and (*b*) as to the form of sides. The top may be (1) level across the entire section between shoulders, either even with or slightly below the top of tie (Figs. 14 and 16); (2) level for from 6 in. to 2 ft. on each side of track center, either from 1 to 3 in. above, level with or slightly below the top of tie, and sloping off to a point at or beyond the ends of the tie (Fig. 17 and line for gravel, Fig. 16); (3) crowned at the center of track, either above, level with or below top of tie, and sloping off to a point at or beyond the ends of the tie (Figs. 15, 18, 19, 20 and 21). Where section (1) is used on double track a central gutter is sometimes provided by depressing the top of ballast between the tracks. Where sections (2) and (3) are used on double track the top slopes may be carried to an intersection between the tracks thus forming a gutter (Figs. 15, 19, and 21) or the slopes may extend only to the inner ends of the ties and the ballast be level between the tracks (Figs. 17 and 18).

The sides of the ballast may be formed in the following four ways: (*a*) There may be no shoulder, the ballast sloping from between the rails directly to the ballast line, as in Fig. 20. The slope may be a plane or formed to a radius of about 6 ft. (see line of gravel ballast, Fig. 16).

(*b*) The side may be rounded off from the end of tie to the ballast line, as shown in Figs. 14 and 21 (*C*). (*c*) The top and side planes may intersect at or beyond the end of tie, forming a sharp corner or shoulder, as shown in Figs. 15, 16 and 19. (*d*) The intersection of the top and side planes may be rounded off to a radius of from 6 in. to 4 ft., forming a round shoulder, as shown in Figs. 18 and 21 (*A*) and (*B*).

A material which drains poorly is generally given the form of section (*a*), the ballast being kept away from the ends of ties. This section is more commonly found on Class C lines. Section (*b*) is used for stone, gravel, cinders, etc., but less frequently for stone. The use of sections (*b*), (*c*) and (*d*) either is governed by local conditions or is a matter of opinion of the railway official. Doubtless with a given ballast equally good results can be obtained with any of the three.

Where there are two or more tracks on curves of small degree it is the practice of most railways to maintain the same distance between track centers as on tangents. The Norfolk and Western spaces tracks 13 ft. center to center on curves and tangents up to a curvature of 9°. The distance is increased 3 in. for 9° curves, 6 in. for 10° curves, 9 in. for 11° curves and 1 ft. for 12° curves. On the Philadelphia and Reading the rule is to increase the distance on curves, center to center of tracks, over that on adjacent tangents by 2 in. for each degree of curve, with a maximum spacing of 14 ft. center to center. In case the outer track has a greater superelevation than the inner track, the spacing given by this rule is increased two and one-half times the difference in superelevation of adjacent tracks. On most railways the double-track section is the single-track section increased by the distance between track centers.

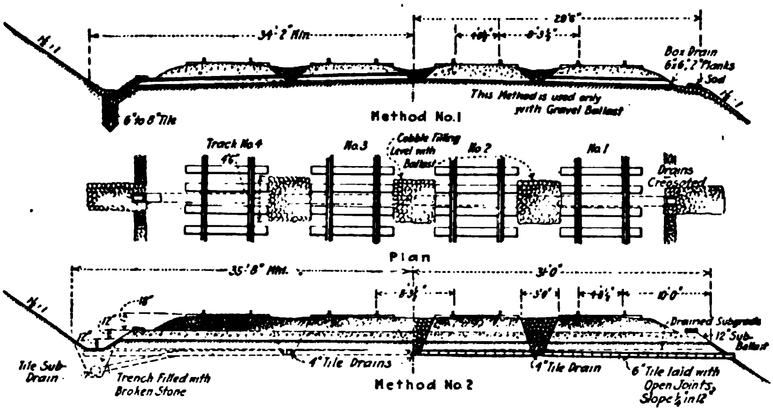


FIG. 13.—Standard roadbed drainage, N. Y. C. & H. R. R. R.

Where the ballast is depressed to form a central drain between tracks of a multiple track line, water is carried to the side ditches by cast-iron or vitrified clay pipe drains or wooden boxes laid in the ballast between the ties and placed from 400 to 600 ft. apart. Two methods used for draining the four-track lines of the New York Central are shown in Fig. 13. Method No. 2 is used in all cases, except rock cuts, where wet or non-drying subgrade is encountered. A similar method of treatment is used when necessary with single- and double-track roadbed.

Table 4 gives the depth of ballast used by various railways.

TABLE 4.—DEPTH OF BALLAST USED BY VARIOUS RAILWAYS[1]

Name of railway	Class of track	Kind of ballast	Depth of ballast under tie in inches	
			At center of tie	At end of tie
Baltimore and Ohio...	A, B, C	Rock, hard slag, gravel, granulated slag, cinders.	12	12
Boston and Maine.....	A	Gravel.	12	12
	B	Gravel.	12	15
Canadian Pacific......	A	Rock, gravel, cinders.	7	9
	B	Gravel, cinders.	7	9¼
Chicago and Alton....		Rock, slag, gravel.	12	13½
Chicago, Burlington and Quincy		Rock, gravel, cinders, burnt clay.	8 to 12	8 to 12
Chicago Great Western	A	Rock, gravel, cinders.	12	13
	B	Rock, gravel, cinders.	9	10
	C	Rock, gravel, cinders.	6	7
Chicago, Milwaukee and St. Paul	A	Gravel, burnt clay, cinders.	12	12
	B		10	10
	C		8	8
Pennsylvania.........	....	Rock, gravel, cinders.	6	7
Rock Island Lines and St. Louis and San Francisco.	A, B, C	Rock, slag, gravel, cinders, disintegrated granite, sand, chats.	6 to 10	6 to 10
St. Louis Southwestern		Rock, gravel, cinders, sand.	12	13

[1] Condensed from table, page 345, Vol. 12, Part I, Proceedings, Am. Ry. Eng. Assn.

36. Broken Stone Ballast.—Experience shows that the very best ballast is that of artificially broken stone of a hard rock, such as basalt, which breaks with an angular fracture and does not pulverize under the action of traffic or track tools. Broken stone thus used is called "stone ballast" or "rock ballast." The best results are obtained by the use of stone of such size that the largest piece will in any position pass through a ring 2½ in. in diameter and will not pass through a ring ¾ in. in diameter. A few engineers favor larger-sized stone, specifying a maximum 3½-in. ring, believing that the smaller sizes bind together and become too hard and compact in the track. The use of smaller-sized rather than larger-sized stones appears to wear the ties less, is less noisy, is easier tamped and handled and gives a better surface at less labor. The broken stone should, in any case, be free from dirt, dust or rubbish.

Next to the depth of ballast under the tie, the quality of the stone is of most importance. The American Railway Engineering Association recommends the following physical tests for broken stone ballast. Other things being equal, the maximum or minimum results as indicated should govern in the selection of the stone to be used.

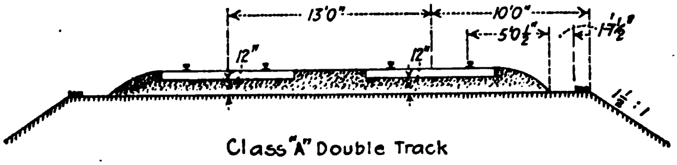


Fig. 14.—Ballast section for stone and hard slag, Class A track, B. & O. R. R.

(*a*) Weight per cubic foot—a maximum.
(*b*) Water absorption in pounds per cubic foot—a minimum.
(*c*) Percentage of wear—a minimum.
(*d*) Hardness—a maximum.
(*e*) Toughness—a maximum.
(*f*) Cementing value—a minimum.
(*g*) Compression test—a maximum.

Too large a size of stone leaves too many voids and thus reduces the stability of the track.

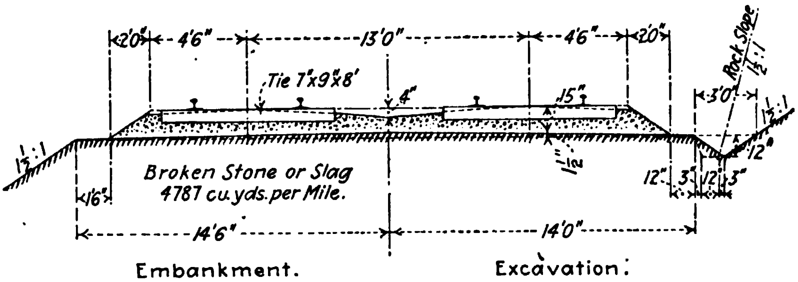


Fig. 15.—Ballast section for broken stone or slag, U. P., S. P., and O. S. L.

In cross-section the ballast may be level with or about an inch below the top of tie, or may be level with top of tie at center of track and slope away on each side so as to clear the rail by about an inch. The sides may be rounded off or slope directly from end of tie, or the ballast may be carried out to a square or round shoulder from 1½ to 6 in. beyond the end of tie. The sections shown in Figs. 14, 15, 16, 21 (*A*) and (*B*), and Method No. 2 of Fig. 13, are for broken stone. The side slopes are usually 1½ to 1, although a few railways specify flatter slopes, as

1¾ to 1 on the L. S. &. M. S. and 2 to 1 on the C. R. I. & P., Frisco Lines and the Pennsylvania Lines West. The sides are frequently placed by hand for appearance and have the toe lined up by hand-laying a row of stones against a board. Though requiring considerable extra labor, this has the advantage of immediately showing, by a broken toe line, where the ballast is being forced out of position under the tie.

Forks should always be used for placing ballast in the track in order to avoid getting any dirt in the track. Conversely, shovels should be used for removing the ballast from the track so that also all dirt will be removed. Stone ballast will drain almost perfectly as long as it is clean, but unfortunately the ballast in time gets dirty, even though the best of care is taken of it. Dust and dirt from the adjacent right-of-way, stirred up by passing trains, soot and cinders from the locomotives, and mud from the roadbed below will eventually work into and clog it. Once this occurs the ballast will retain water like any inferior ballast. For this reason even stone ballast should be kept away from the rails where the rails carry electric currents. This is done on the P. & R., W. & L. E., D. L. & W., etc., by having the top of ballast level at 1 in. below top of tie. On other roads the same thing is accomplished by using either section (2) or (3), Art. 35, for the top of ballast, so that at the rail the surface will be an inch or more below the base of rail. On the New York Central Lines the ballast is 1 in. below top of tie at center of track and slopes to 2 in. below top of tie at end of tie.

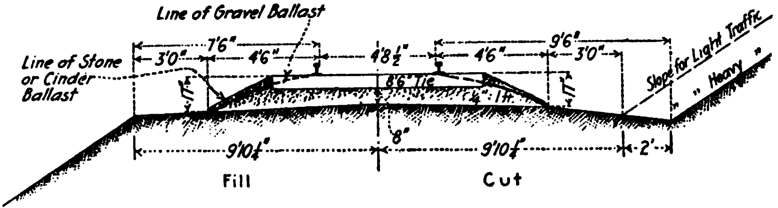


Fig. 16.—Single-track ballast section for stone, gravel or cinder ballast, P. R. R.

37. Cleaning Ballast.—The evils resulting from dirty stone ballast can be cured in two ways: (*a*) by raising the track and putting in from 4 to 10 in. of new ballast, or (*b*) by cleaning the ballast. The tendency in the past has been to use the first method which is by far the more expensive. During the past few years maintenance of way engineers have found that equally beneficial results can be secured at much less expense by removing the ballast and cleaning it. This may be done (1) by removing the ballast and replacing it with ballast-forks, the dirt being screened out through the tines of the fork; (2) by removing the ballast and passing it through a specially prepared screen before replacing it in the track. The latter method has been used extensively on the Baltimore and Ohio, where the cost was about one-half that of cleaning with forks.

On the New York Central and Hudson River R. R. each section-gang cleans the ballast in a continuous stretch on a part of its section each year, by forking it over. On most heavy-traffic lines the ballast is cleaned at each place where a tie-renewal is made. This results in the ballast being cleaned once each period of time equal to the average life of ties in a given track. This would be from 6 to 10 years. The drainage condition of the track would vary between the limits of freshly cleaned ballast around a newly installed tie, to ballast perhaps completely clogged around an old tie which may be only a few ties distant from one just installed. However, the average drainage condition of ballast cleaned as ties are renewed singly is considerably better than it would be if the ballast were cleaned in a continuous stretch at one time and then not cleaned again for a period equal to the average life of ties. This is because ballast cleaned around one tie will to some extent help the drainage of very dirty adjacent ballast. The volume of dirt obtained by cleaning dirty ballast is about 30 per cent. of the volume of ballast before being cleaned. Where there are two or more tracks the ballast should be cleaned between tracks to a depth of 6 in. or more below the bottom of ties. On the berm the ballast should be cleaned down to the roadbed. Between ties the ballast should be cleaned to the bottom of the ties and a cross ditch extending down to subgrade should be cleaned, preferably one under each length of rail, and in any case one each 50 ft. After cleaning ballast, a certain amount of new ballast, varying from 5 to 20 per cent., will always be needed. Not all of the volume lost is foreign matter. Some of it is composed of fine particles of stone that have been disintegrated by the action of the elements, traffic, and repeated tamping. At terminals stone ballast should be cleaned at intervals of 1 to 3 years; on heavy-traffic coal-lines at intervals of 3 to 5 years; and on light-traffic lines at intervals of 5 to 8 years.

38. Broken Stone Ballast Plants and Cost of Stone Ballast.—The first cost of stone ballast is considerably greater than that of other kinds, but the advantages also are greater. The most important of these are (*a*) less liability of washouts, (*b*) no dust, (*c*) no heaving from the action of frost, (*d*) weeds do not grow, and (*e*) holds line and grade best of any ballast.

Several railways operate quarries and crushing plants for the sole production of their stone ballast. The Michigan Central[1] at present has in service two large quarries and crushing plants, one at Joliette, Ill., and one at Hagersville, Ont. The plant at Hagersville has been operated about 9 years and with very satisfactory results. The quarry is worked to a maximum depth of about 29 ft. The quarry face is served by forty 4-ft. gage tracks which carry 3-cu. yd. automatic dump cars. The drilling is done by a gang of about 10 men and about 40 men are employed in loading the stone into the cars. The cars are pulled to the crusher by horses and are there hauled up an incline to the dumping platform by a friction hoist. The crusher-run stone varies in size from ¼ to 2½ in. The total labor force required is about 80 men. Most of the laborers are paid on a piece-work basis. The season of 1913 included 190 working days and the detailed cost of operating the plant for this period was as follows:

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[1] Railway Age Gazette, Feb. 20, 1914.

Item	Cost per cubic yard of ballast
Loading stone in quarry	$0.11200
Hauling stone to crusher	0.04494
Drilling and blasting	0.08012
Crushing and loading ballast	0.06637
Supervision, repairing and pumping	0.02516
Miscellaneous	0.01274
Hauling and spotting ballast	0.11449
Unloading ballast	0.01176
Ballasting	0.29145
Total cost of ballast in track	$0.75903

The average output of the plant was about 745 cu. yd. per day. The cost of the ballast loaded on cars ready for shipment at the plant was but $0.34133 per cubic yard. The average haul of the ballast was 129.07 miles.

39. Gravel Ballast.—Gravel is the most commonly used of all materials for ballast and varies greatly in quality. It may be coarse and clean, giving good drainage; or sandy and dusty; or loamy and quick to cement, thereby giving a foothold for vegetation; and may also be full of large stones which will make an uneven and rough-riding track. As a rule, pit-run gravel is put directly into the track although it generally contains objectionable matter, such as sand and clay. A few roads screen, and some screen and wash, the gravel before putting it into the track. Excellent results have been obtained by so doing. The screened gravel is ordinarily from ⅛ in. to 2 in. in size.

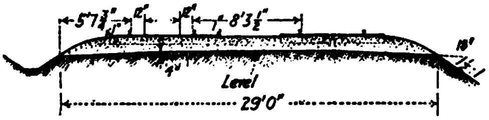

FIG. 17.—Double-track ballast section for gravel or engine ashes, C. P. R.

The American Railway Engineering Association recommends that for Class A roads, bank gravel which contains more than 2 per cent. of dust, or 40 per cent. of sand, should be washed or screened. Washed or screened gravel should contain not less than 25 per cent. nor more than 35 per cent. of sand. For Class B roads, bank gravel containing over 3 per cent. of dust or 60 per cent. of sand, should be screened or washed.

Washed or screened gravel should not contain less than 25 per cent. nor more than 50 per cent. of sand. For Class C roads any kind of gravel can be used. The above percentages are by volume. All material passing a No. 10 screen and being retained on a No. 50 screen is considered as sand.

There are a variety of cross-sections in use for gravel ballast. These depend on the climatic conditions, traffic, quality of material, etc. For ordinary gravel, where frost and water have to be considered, the best results have been obtained by having the gravel level with the top of the tie for 2 or 3 ft. at the center of track and then sloping off to 2 or 3 in. below the top of the tie at end of tie. Some roads raise the top of the ballast above that of the tie, filling in 2 or 3 in. over the tie at the center. This undoubtedly holds the tie better, but it also holds a greater amount of moisture around the tie and causes more rapid decay. The depth of ballast under the tie is from 6 to 18 in. The sides are generally given a slope of 2 to 1 or 3 to 1, although a slope of 1½ to 1 will be found on a few railways. The recommended sections of the American Railway Engineering Association for Classes A, B, and C track are shown in Fig. 18 and the Common Standard section of the Union Pacific, Southern Pacific and Oregon Short Line for gravel, burnt clay or cinders is shown in Fig. 19.

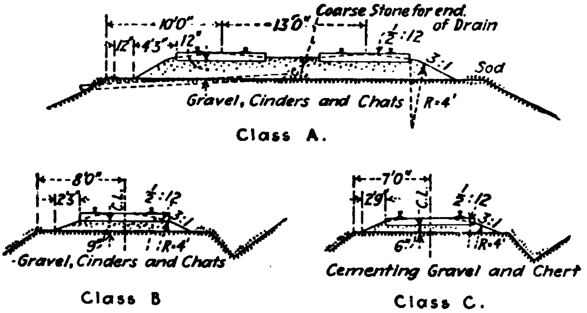

Fig. 18.—Ballast sections for gravel, cinders, etc. (A. R. E. A.).

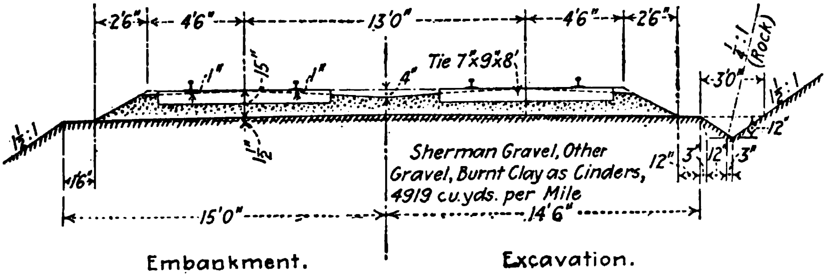

Fig. 19.—"Common Standard" ballast section for gravel, burnt clay or cinders.

Large deposits of excellent gravel occur in different parts of the country. These are of sedimentary origin. The Spokane, Portland and Seattle Railway is built through a very extensive gravel deposit for a considerable distance along the Snake River in Washington. The north bank of the river is high and steep, almost a cliff, and is composed of a gravel bed many feet in depth. In some places the roadbed is a side-hill cut in this bank. Here is one case where the supply of good ballast material is so abundant as to cause trouble, as the gravel on the slope above becomes loosened and slides down on the track.

Since gravel is composed of rounded stones of various sizes its grip upon the tie is less than is that of broken stone. Hence, track gets out of line easier in gravel than in rock ballast. In order to offset the less friction offered by gravel ballast than by rock ballast to the movement of the ties, gravel is generally shouldered out well beyond the end of the tie. Figure 17 shows a gravel ballast section of the Canadian Pacific Railway.

40. Gravel Ballast Washing Plants.—Washed gravel is used to some extent on several railways, among which are the Pennsylvania lines, the Delaware, Lackawanna and Western, and the Lake Shore and Michigan Southern. During 1907 the Richmond, Fredericksburg and Potomac Railway and the Washington Southern Railway completed double-tracking between Richmond, Va., and Washington, D. C. While investigating the scources of ballast, a large gravel deposit was found at Massaponax, Va., about midway between Richmond and Washington. Pit-run gravel was first tried as ballast and made good track but in very dry weather was quite dusty and in wet weather the track was sloppy. It was then decided to install a plant for washing and screening the gravel. This plant was completed late in 1908. The gravel deposit is from 10 to 20 ft. deep. The gravel is excavated by a steam-shovel and dumped into cars which are hauled up an incline and their contents dumped into a bin. From the bin an elevating belt conveyor carries the gravel to a chute. As the gravel falls from the conveyor it is caught by a stream of water which carries it down the chute. The material passes from the chute to a screen and by successive screenings all material smaller than ⅛ in. in diameter is removed. All other material, which was washed free from dust while passing down the chute, goes into a ballast-bin from which it is discharged by gravity. A force of from twenty to twenty-five men is required to operate the plant. The unit costs of producing the first 354,439 cu. yd. of ballast were as follows:

Item	Cost per cubic yard
Loading rough gravel at pit..................	8.95 cts.
Washing and screening......................	11.34 cts.
Hauling and spotting.......................	11.11 cts.
Placing in track (unloading and surfacing).....	26.15 cts.
Total cost of ballast in track..............	57.55 cts.

The cost of this ballast at the plant ready for hauling was but 20.29 cents. Observation of the ballast in the track shows that it drains very well, does not get sloppy under any amount of rain, is dustless, and has appreciably reduced the amount of work required for general track maintenance. The engineers in charge of maintenance estimate that, because of its excellent drainage, the washed gravel will add 2 years to what the life of ties would be if pit-run gravel was used.

41. Slag Ballast.—Slag is the waste product of furnaces for the reduction of ore. It is used in considerable quantities for ballast by railways in the vicinity of blast-furnaces. Coarse slag is almost as durable as broken stone and in many other ways is about as good. In some cases, however, it appears that dry-rot attacks the ties more rapidly than in stone ballast. It has also been claimed that slag causes excessive corrosion of the rails, but observation does not bear this out. A vitreous slag is the best, as the spongy kind is likely to pulverize under the action of traffic and tamping. Vitreous slag broken into pieces similar to broken stone is called coarse slag. At the present time most slag comes from blast-furnaces or iron-works in a granular form, which is the result of dumping the molten slag into water or by playing streams of water on the molten slag as it flows from the furnace. The sudden cooling causes the slag to break up into small particles similar in size to fine gravel. This material weighs only about 53 lb. per cubic foot, which is about one-third the weight of coarse slag. Granulated slag is much inferior to the coarse variety, for a ballast material, and is more or less dusty, but is superior in drainage to cementing gravel, cinders, and sand.

In the past the Norfolk and Western Railway has used a large amount of slag ballast with good results and has found it much cheaper than stone ballast.

The ballast section for coarse slag is the same as for broken stone (Figs. 14 and 15). Granulated slag is given the same section as gravel or cinders (Figs. 17, 18 and 19).

42. Chats and Disintegrated Granite Ballast.—Chats are tailings from mills in which zinc, lead, silver and other ores are separated from the rocks in which they occur. The material is composed of particles of rock, mostly quartz, broken to about the size of a grain of wheat. It is quite heavy, is easily worked in the track, is not excessively dusty, drains fairly well and, being heavy and angular, holds the track well to line. The ballast section is the same as for gravel or cinders (Figs. 17, 18 and 19).

Disintegrated granite occurs in natural deposits throughout the Rocky Mountains from Alaska to Mexico. It weighs about 3000 lb. per cubic yard, occurs in the form of sharp, angular grains about the size of a pea, is easily handled and is not dusty. It drains fairly well but tends to become too compact under the action of traffic. It has been freely used on the Union Pacific Railroad where it has been obtained very cheaply, costing about 25 cts. per cubic yard in the track, exclusive of hauling. The ballast section is the same as for gravel or cinders.

43. Burnt Clay Ballast.—This has been used in England and other European countries for many years and is now used quite extensively for ballast by railways throughout the Mississippi Valley and in the West. The first clay burned in England was used for walks and driveways; that first burned in this country was burned in Chicago, in 1882, by an English company and was put to the same use.

Any clay can be used which is high in iron, lime and alkalies, so that it will vitrify well in burning; is free from sand, gypsum and silt; and does not crumble when exposed to air.

The site for burning is selected on rather low ground not in the vicinity of habitations. The quality and depth of clay is determined by test holes. The top soil should be thin, not over 6 in. deep, and preferably a sticky gumbo. The bed of clay should be at least 6 ft. deep. A breastwork of clay about 4 ft. high is first thrown up and the top and face are covered with a layer 1 to 1½ in. thick of slacked coal, or coal-screenings. A double layer of old ties, or cord-wood, is then laid against the face and on top of the breastwork and a quantity of coal is scattered over it. Coal oil is thrown over the pile and ignited, thus starting the fire. After the fire has burned about an hour a layer of clay 10 or 12 in. thick is spread over it. If the quantity of clay to be burned is large the clay can be handled most economically by drag-buckets operated from a car running on a track in front of and parallel to the face of the pit. Two or 3 days after starting the fire another layer of coal is scattered over the pile. In time this is ignited by the heat which comes through the clay. After the fire has burned 5 or 6 days another layer of clay is added. Every 5 or 6 days a 1- to 1½-in. layer of fuel and then a 10- or 12-in. layer of clay is added until the required amount of ballast has been burned. One ton of slacked coal will burn about 4 cu. yd. of ballast. If the fire is not clean or the clay is not thoroughly burned, the ballast is liable to disintegrate in the track and turn to mud. The length of the pit or kiln varies from 500 to 4000 ft. and the finished pile is usually about 20 ft. wide and 10 ft. high. The finished material is red in color, weighs from 40 to 50 lb. per cubic foot, and absorbs water readily. Specifications should limit the absorption to 15 per cent. by weight. As the material is light, it must be used liberally to hold the track in line. It costs from 80 to 85 cts. per cubic yard in the track. No particles of the material should be larger than will pass through a 4-in. ring.

Practically every railway that has used this kind of ballast pronounces it a success. It is easily handled, drains well, prevents the growth of vegetation, does not heave, and is less dusty than cinders and pit gravel;

but in the course of time it may disintegrate under the action of the elements, traffic and tamping, so that it will become dusty and drain less rapidly. If overburned or if the fire was too hot, it may contain clinkers which are a considerable source of trouble to the trackmen. Care in burning will prevent the formation of these. The ballast section used is similar to that for gravel or cinders (Fig. 19). The minimum depth below the tie should be 8 in. The Chicago, Milwaukee and St. Paul has used side slopes of 2½ to 1. On this road, ballast in the track 18 to 19 years was found to be in good condition. However, the normal life of this kind of ballast is probably from 10 to 12 years.

44. Cinder Ballast.—The residue from the coal used in locomotive and other furnaces makes a cheap and fairly good ballast for branch lines having light traffic, for sidings and for yard-tracks near the point of production, and as sub-ballast over wet roadbed (Art. 32). Being quite porous, cinders drain fairly well and the ballast does not heave much from the action of frost, vegetation does not grow and the material is easily handled, but the ballast is quite dusty. The ballast section is the same as for gravel (Figs. 17, 18 and 19).

45. Chert and Cementing Gravel Ballast.—Chert is an impure flint or hornblend. It is principally used in America as a ballast material in the southern States where extensive deposits of it occur. In the natural state it contains clay, which greatly reduces its desirability because of the cementing property of the clay. In dry weather the clay pulverizes and the ballast is dusty, while in wet weather the clay prevents good drainage. Because of the poor drainage afforded by cementing chert or gravel the ballast section used is similar to that shown in Fig. 20. The material is kept away from the ends of the tie so that the water can drain more freely from around the tie.

46. Sand and Shell Ballast.—Sand is a relative term. Soil may be classified as follows according to the size of particles:

Material	Pass through	Retained on
Fine gravel	No. 10 screen	No. 18 screen
Coarse sand	No. 18 screen	No. 32 screen
Medium sand	No. 32 screen	No. 70 screen
Fine sand	No. 70 screen	No. 160 screen
Very fine sand	No. 160 screen	No. 230 screen

Particles finer than this are called silt and the very finest, clay. Under light traffic, sand makes a good ballast material, but it requires constant attention and much maintenance work. The particles of sand are carried away by the wind, very rapidly washed away by the rains, and churned from beneath the ties by the action of traffic. It makes a very dusty ballast, retains moisture and hence is liable to heave, does not hold track well to line and surface and causes excessive wear to all exposed moving parts of the engine and car machinery. Sprinkling with oil keeps down the dust and prevents erosion by the elements. The form of ballast section is similar to that for gravel, except that the shoulders should be made wider in order to hold the track properly, since sand is lighter than gravel.

Oyster shells have been used to some extent by railways along the Atlantic Coast, particularly around Chesapeake Bay. Their first cost for ballast purposes is low, being about 25 cts. per cubic yard, and they drain fairly well. They are light and do not hold the track well, are rapidly pulverized under any traffic and are extremely dusty. The ballast section is similar to that for sand.

47. Earth Ballast.—Earth ballast, sometimes called "dirt" or "mud" ballast, should be used only when a more suitable material cannot be obtained. It is composed of the natural soil along the line, is the cheapest of any ballast material in first cost and is one of the most extensively used materials on branch lines, or Class C track, but is the most troublesome and expensive of any to maintain.

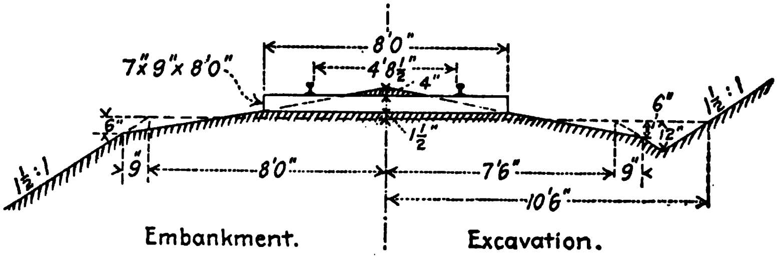

FIG. 20.—Section for earth ballast, S. P. Co. and O. S. L. R. R.

Its quality varies greatly. In any case it should be taken from the subsoil after having first removed all surface soil. It drains poorly; heaves from frost; becomes soft in wet weather, often rendering the track unsafe; cakes in dry weather, in which condition it is very hard to work; allows vegetation to grow, and in dry weather is very dusty.

In any climate where earth ballast is used, the very best drainage is absolutely necessary to keep the track in any semblance of a good condition. The earth is generally filled 3 or 4 in. over the top of tie at the middle and sloped to the bottom of tie at the end. No attempt is made to prevent the growth of weeds, as vegetation of any kind reduces the dust nuisance and the erosion caused by rain. The section for earth ballast, as used on the Southern Pacific Co. and the Oregon Short Line Railroad, is shown in Fig. 20.

48. Oiling Ballast.—Dusty ballast is objectionable because it increases the wear of machinery and causes discomfort to the passengers, especially in summer.. In 1896 the West Jersey and Seashore Railway tried to reduce the dust nuisance by sprinkling the track with oil. The results were more or less satisfactory and many other railways have since followed this example. Crude petroleum, or a residuum of crude petroleum, is used. The first application requires about 2000 gal. per mile of single track and costs about $80 per mile. Subsequent applications require about half this amount. The application is made in May or June and generally one application a year is required. Except in the case of sand, the oil has no effect upon the work of keeping the track in line and surface. With sand the effect is an increase in maintenance work. The oil makes the sand incohesive and the track works out of line and surface very rapidly. Only ballast which is very dusty or where the dust nuisance is very objectionable should be oiled. Even the oil does not lay all the dust, and if the ballast is originally only a little dusty this "clean dust" is less objectionable than the fine oily dust which comes from the oiled track.

The railways in California quite commonly spray oil on the roadbed for the purpose of killing vegetation.

49. Quantity of Ballast Required.—No general table can be given for the volume of ballast required per mile of track, because of the very great variety of ballast sections to be found on different railways. Once the section and size and spacing of ties are known, it is a very easy matter to compute the volume required. It is ordinarily unnecessary to know accurately the volume of ballast used in maintenance work, as the work of applying it is usually done by the regular section forces, and the material is produced by the railway. But in some cases the work of raising and reballasting track, or ballasting track which previously had dirt ballast, is done by contract at so much per cubic yard of ballast in the track. It then becomes necessary to determine the volume of ballast actually placed in the track. This is done by cross-sectioning the track before and after the ballast is applied. Cross-sections are taken each 50 or 100 ft. and the volumes computed as in earthwork. The number of rod readings required for each cross-section will depend on the form of roadbed and ballast section. A level roadbed and a level ballast section with sides sloping away from the shoulder will require four readings, one at each shoulder and one at each toe of ballast. If the ballast is level but the roadbed is crowned at the center, an additional reading must be taken at the center, and so on for other forms of section. Much computation will be saved by preparing a ballast table which will give volumes for all cross-sections within the allowable limits.[1] For the double-track sections shown in Figs. 15 and 19, 4787 and 4919 cu. yd., respectively, are allowed per mile. These are the theoretical volumes, plus a 2 per cent. allowance for loss, depressions in the roadbed, etc.

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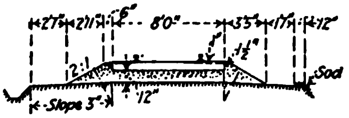
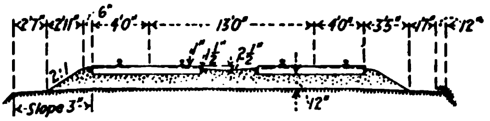
[1] For ballast table used on the Missouri Pacific Ry. see Engineering and Contracting, Mar. 20, 1912.

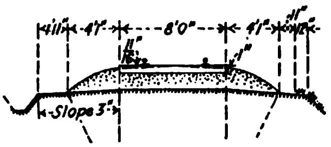
For the four-track section shown in Fig. 11, 18,600 cu. yd. of stone ballast and 11,200 cu. yd. of cinder ballast are required per mile. Figure 21 shows the standard ballast sections for Class A track on the St. Louis & San Francisco R. R. (Frisco Lines). The size of tie is 6 in. × 8 in. × 8 ft., and the spacing is 20 to a 33-ft. rail. On double track, for stone and slag, the ballast is depressed 2½ in. below top of ties midway between tracks, while for gravel, etc., it is depressed 1¾ in. On less important track the same form of section is used, except that the depth of



Single Track.
(A)



Double Track
(B)



Single Track
(C)

FIG. 21.—Ballast sections, Class A track, St. L. & S. F. R. R.

TABLE 5.—VOLUME OF BALLAST REQUIRED PER MILE OF LINE, ST. L. & S. F. R. R.

Ballast	Depth of ballast under tie. Inches.	Single track	Double track
		cubic yards per mile	cubic yards per mile
Broken stone and slag	6	1644	3645
Broken stone and slag	7	1850	4062
Broken stone and slag	8	2061	4486
Broken stone and slag	9	2278	4914
Broken stone and slag	10	2500	5348
Broken stone and slag	12	2961	6233
River gravel, chats, sand, cinders	6	1971	4039
River gravel, chats, sand, cinders	7	2207	4487
River gravel, chats, sand, cinders	8	2448	4940
River gravel, chats, sand, cinders	9	2694	5397
River gravel, chats, sand, cinders	10	2943	5858
River gravel, chats, sand, cinders	12	3451	6790

ballast is less. In Table 5 is given the yardage of ballast per mile for these sections both for single and double track and for depths of ballast from 6 in. to 12 in.

The volume of ballast required on curves is larger than on tangents, because the outer rail is elevated while the inner rail is kept at the same level as on tangents. Figure 22 shows the single-track roadbed and ballast section used on curves by the Northern Pacific, for clean gravel, sand or cinder ballast. On single track the width of roadbed on tangents is 18 ft. The roadbed has a crown of 3 in. at the center, and the top of the ballast at the center of the track is 19 in. above the crown of the roadbed. The ballast is even with the top of the ties at the center of the track and slopes to 3 in. below the top at the ends of the ties. As the toe of the ballast is carried out to the rounded edge of the roadbed, the width of roadbed must increase as the superelevation increases. The following table gives the dimensions *B*, *C*, *D* and *W* shown in the figure for changes in the superelevation *A*. The width for double track is 13 ft. greater than the values given for *W*, and the height of crown is 5 in. The other dimensions are the same for double as for single track. Between the tracks the top of the ballast of the outer track is continued inward at the same slope to intersect the sloping outer shoulder of the inner track which is formed as for single track.

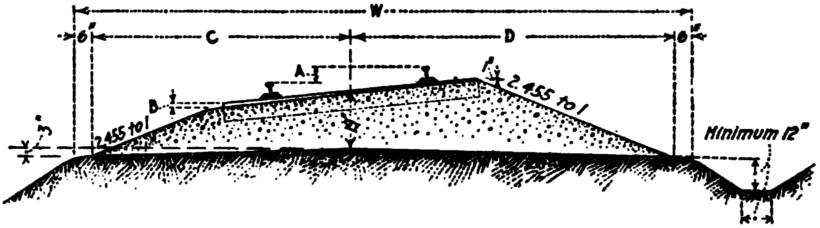


FIG. 22.—Single-track ballast section on curves, N. P. Ry.

For $A = 1''$, $B = 3''$, $C = 8' 5''$, $D = 8' 9''$, $W = 18' 2''$.
For $A = 2''$, $B = 3''$, $C = 8' 4''$, $D = 9' 0''$, $W = 18' 4''$.
For $A = 3''$, $B = 3''$, $C = 8' 4''$, $D = 9' 4''$, $W = 18' 8''$,
For $A = 4''$, $B = 2''$, $C = 8' 3''$, $D = 9' 7''$, $W = 18' 10''$.
For $A = 5''$, $B = 2''$, $C = 8' 2''$, $D = 9' 10''$ $W = 19' 0''$.
For $A = 6''$, $B = 2''$, $C = 8' 1''$, $D = 10' 01''$ $W = 19' 02''$.

The volume of ballast required per mile is as follows:

	Single track	Double track
On tangents	3600 cu. yd.	6660 cu. yd.
For $A = 3''$	3980 cu. yd.	6840 cu. yd.
For $A = 6''$	4470 cu. yd.	7630 cu. yd.

CHAPTER V

WOODEN TIES

50. Consumption of Ties.—The largest individual item of cost in track maintenance, with the exception of labor, is that of tie-renewals. In view of this, every possible means should be taken to effect an economy in the item. In reality the work of tie-renewals on many railways is given little attention from an economic standpoint.

From 85 to 90 per cent. of all ties purchased by American railways are used for renewals and the remainder are used on new construction. In 1911 the steam and electric railways of the United States purchased 135,053,000 wooden ties. In 1913 the total number of ties purchased in Canada was 19,881,714, 2 per cent. of which were for use on electric lines. In the United States about 6 per cent. of the total are consumed annually by electric railways. It is seen, therefore, that the total present yearly consumption for Canada and the United States is about 155,000,000 ties. A 6-in. by 8-in. by 8-ft. tie contains approximately 32 board-ft.; hence the yearly consumption of timber for ties is over 5,000,000,000 ft. board-measure. This costs close to $15 per thousand feet, B. M., so that the yearly cost of material for ties is about $75,000,000, a sum well worth trying to reduce by every possible economy in tie-renewals.

In many localities the sources of supply have been so exhausted that the railways are forced either to use ties of an inferior wood or to transport good ones from distant sources. In the past there has been much wastefulness in the use of timber for all purposes and the price of lumber has rapidly increased. The average price paid for ties on the Baltimore and Ohio has increased from 50 cts. in 1904 to 70 cts. in 1913, or an increase of 40 per cent. in 10 years.

51. Railway Tie-timber Plantations.—The enormous consumption of timber is rapidly depleting the forests, but in the face of a threatened timber famine the North American governments have done almost nothing toward reforestation of the denuded areas. The cutting away of the forests is serious also because of the effect upon climatic conditions.

In several cases railways have taken the initiative and have started timber plantations to provide a future tie supply. The Pennsylvania Railroad has done more in this way than any other road in America. Between the years of 1902 and 1909 trees were planted each year on idle land owned by the company, until a total of 3,430,000 trees were planted, about two-thirds being black locust, almost one-third red oak, and a few mixed species. These trees are distributed over 40 plantations. The Louisville and Nashville R. R. has planted over 2,000,000 trees of catalpa, walnut, locust, and poplar. Other railways having less extensive plantations are the Chicago, Burlington and Quincy; Delaware, Lackawanna and Western; Southern Railway; Michigan Central; Southern Pacific, and Union Pacific. In some cases the results up to the present have not been altogether satisfactory, but in no case has the experiment been continued long enough to be able to draw definite conclusions.

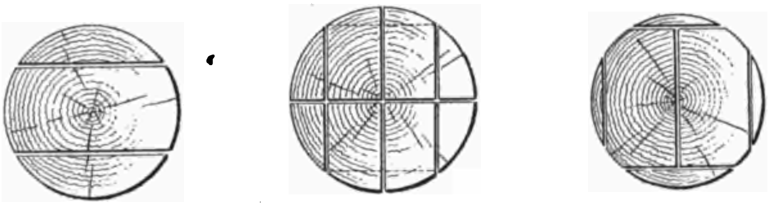
Besides the required amount of timber for ties, railways require a large amount of timber for fence-posts, telegraph-poles and piles. Usually several posts can be cut from the remaining parts of a tree after all tie-timber has been removed. Small trees can be cut for telegraph-poles. Piles, however, require only first-class straight timber. The amount of timber required yearly by railways for renewal of posts, poles and piles is from 50 to 75 per cent. of that required for ties.

The present supply of timber should be protected and conserved in every way possible by using a chemical preservative treatment for ties, by using tie-plates and screw-spikes, by taking every known precaution to prevent forest fires, and perhaps by reducing the tax on timber-land so that the timber could be held for future consumption. Instead of maintaining artificial forests, many railways could better acquire existing forest areas and so preserve them that only mature timber would be cut and a new growth constantly would be coming on.

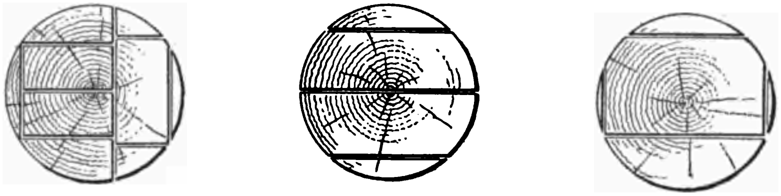
During recent years many substitutes for timber ties have been produced, but for many years to come the wooden tie will continue to be used in enormous quantities. However, by using the proper measures to protect the ties from decay and mechanical wear their life can be considerably increased. A tie of inferior wood may thus be made to give as good or better service than the best of ties without such protection. But there is no economy in using inferior ties just because they are cheap, unless they are protected in this way. The cost of placing them is the same as for good ties, they give worse service, require more frequent attention, and the subsequent frequent disturbances of the track make it impossible to maintain it in a uniform operating condition.

52. Definitions.—A tie made from a tree of such size that not more than one tie can be made from a section is called a **pole-tie,** and is hewed or sawed on two parallel faces (Fig. 23*a*). A tie made from a tree of such size that, by splitting, two or more ties can be made from a section is called a **split tie** (Fig. 23*c*). An inferior tie, called a **slab tie,** is sometimes made from the first or outside cut of a log. A **sawed tie** has the two sides and two faces sawed. The upper or lower plane surface is called the face. A **quartered tie** is one made from a tree of such size that four ties are made from a section (Fig. 23*b*). A **slabbed tie** is one sawed only on the two faces (Fig. 23*d*). If the two faces are of equal width the slabbed tie is also a pole-tie (Fig. 23*a*), but if the lower face is wider than the upper, it is called a **half-round tie** (Fig. 23*d*). A **hewed tie** must be hewed on at least two surfaces other than the ends.

The amount of sap-wood is always limited by tie-specifications. If the cross-section shows more than the specified amount of sap-wood, the tie is classed as a **sap-tie.** If more than the specified amount of sap-wood shows on only one or two corners, but does not measure more than 1 in. on either corner, measured diagonally across the tie, it is classed as a **heart-tie.** A **strict heart-tie** has no sap-wood. A fairly good tie can be made from a tree too small to make a pole-tie, by allowing part of the original surface of the tree to show on one or more corners, as shown in Fig. 23*e*. This is called a **wane-tie.** A tie made from a tree, the resin or turpentine of which has been extracted before felling, is called a **tapped tie.** **Cull ties** are those which do not conform to the specifications. A tie used under a rail-joint is spoken of as a **joint-tie.** **Intermediate ties** are those between joint-ties. A member or members of a set used to support the switch-point operating mechanism is called a **head-block.** A **switch-tie** is one of a set used to support a turnout. A tie which has been subjected to a process designed to protect it from decay is called a **treated tie.** **Shakes** are separations of the wood-fiber, due to the action of the wind on the standing tree. **Checks** are cracks in the wood caused by seasoning.



Pole Tie -a- Quartered Ties -b- Split Ties -c-



Split Ties -c- Slabbed. Ties -d- Wane Tie. -e-

FIG. 23.—Types of ties.

53. Tie-woods and their Properties.—White oak is the species most largely used and is by far the best of all untreated woods for ties, both as to wear and durability. It is a very hard, tough wood and decays slowly. The ultimate failure of the untreated tie is generally from decay rather than from wear. The average life under heavy traffic is about 9 years, and 12 to 15 years under moderate traffic. Bur-oak, rock-oak and chestnut-oak are next in value, lasting 6 to 8 years. Black and red oak, pin or swamp-oak and water-oak are inferior woods and will last only 4 or 5 years when untreated. Pine, in its numerous varieties, is used in quantities second only to oak. It is a comparatively soft wood, but is slow to decay. Long-leaf heart pine has been known to last 12 years in the South. Pines high in pitch check badly. Yellow pine is preferable to oak for bridge-ties and bridge-timbers as it warps less. Of all pines used, about 75 per cent. is southern yellow or long-leaf pine, 20 per cent. western yellow pine from the Rocky Mountains and Pacific Coast region, and 5 per cent. white and Norway pine. Chestnut is almost as durable as oak, lasting from 5 to 8 years, but because of its very straight grain tends to split easily. It is used extensively for posts as well as for ties. Cedar is very durable and will resist decay from 12 to 15 years, but it is a light wood and fails much sooner from rail-cutting and the redriving of spikes. Hemlock is neither hard nor durable and its life varies considerably for different track conditions, averaging about 3 years. It is used rather extensively because of its cheapness. Spruce and tamarack have about the same properties and life as hemlock and cost about the same. Black and red cypress are much used in the South where they grow in considerable quantities. The wood is quite soft but resists decay well. Redwood is used extensively in California. The wood is soft but decays slowly. Where used on the Southern Pacific it lasts 12 years when treated and with tie-plates, and 5 years untreated and without tie-plates. The majority of all other woods, with but few exceptions, are of little value unless chemically treated.

In Australia the native hardwoods such as eucalyptus and ironbark are used and last from 15 to 30 years. A number of years ago Australian eucalyptus was brought to California where it was much discussed at the time and many plantations were started, some of which still exist. It is a quick growth tree and will obtain a size of 15 to 20 in. in diameter in about 15 years. It requires little water and the wood is very hard and tough. It answers every requirement for a tie-wood, but is quite expensive because of the very limited supply. Some timber species which hold out promise as sources of tie supply because they grow rapidly, reproduce readily, take preservative treatment facilely, and have extensive ranges, are loblolly-pine and willow-oak in the South; cottonwood and willow in the South and Middle West, and white pine and red oak in the North.

The only proper classification of woods for ties is on a basis of actual wear in the track, that is, the power of a tie of any given species of wood to hold the spikes and resist rail wear and decay. The Chicago, Burlington and Quincy recently conducted tests with ordinary cut spikes to determine the spike-holding power of different woods. The results of the test are given in Table 6. With these tests as a basis, the Chicago, Burlington and Quincy now classifies all ties broadly as hardwood and softwood. Each of these classes is subdivided into woods for use without a preservative treatment and woods to be used only when treated. The classification for hardwoods is (*a*) for use untreated, white oak, bur-oak, chestnut, locust, black walnut, mulberry and sassafras; (*b*) to be used treated, red oak, black oak, pin-oak, water-oak, Turkey-oak, Spanish-oak, black-jack, beech, hickory, ash, elm, hard maple and cherry. The classification for softwoods is (*a*) for use untreated, cedar and cypress; (*b*) to be used treated; short-leaf pine, loblolly-pine, bull pine, lodge-pole pine, Douglas fir, tamarack, hemlock, gum, tupelo, birch, sycamore, soft maple, hackberry and butternut.

TABLE 6.—SPIKE-HOLDING POWER OF VARIOUS WOODS[1]

Kind of wood	Maximum resistance to pulling, in pounds		Resistance in per cent. of that of white oak	
	Untreated	Treated	Untreated	Treated
White oak	7,870	....	100	....
Water-oak	....	6,780	....	86
Black oak	....	7,230	....	92
Red oak	6,460	7,730	82	98
Bur-oak	....	9,210	....	117
Ash	....	7,730	....	98
Chestnut	5,190	5,200	66	66
Elm	7,290	7,500	93	96
Beech	8,180	8,900	104	113
Poplar	4,920	5,670	62	72
Loblolly-pine	3,630	4,210	46	55
Sweet-gum	5,040	5,300	64	67
Hemlock	5,633	4,200	72	53
Soft maple	6,513	5,887	83	75
Hard maple	10,177	8,960	129	114
Hickory	10,153	10,433	129	133
Cypress	3,163	2,840	40	36
Birch	6,337	5,907	80	75
Cottonwood	2,810	2,743	36	35
Northern hard maple	10,393	....	132	....
White cedar	1,467	....	19	....

[1] From Railway Age Gazette, June 16, 1911.

This classification is representative of the use of woods treated and untreated on all important railways. In addition, redwood is used untreated extensively by railways in the West; long-leaf strict-heart yellow pine is often used untreated, though much more servicable if treated, and spruce should be used only when treated. Black walnut is sometimes treated and catalpa is used untreated.

Of all the ties purchased in the United States by steam and electric railways in 1910, the different woods were in the following proportions: (1) oak, 46 per cent.; (2) southern pine, 18 per cent.; (3) Douglas fir, 8 per cent.; (4) chestnut, 5 per cent.; (5) cedar, 5 per cent.; (6) cypress, 4 per cent.; (7) tamarack, 4 per cent.; (8) all others, about 10 per cent. In Canada the woods were used in the following proportions in 1913, including steam and electric railways: (1) jack-pine, 39.1 per cent. (2) white cedar, 12.3 per cent.; (3) Douglas fir, 12.2 per cent.; (4) western larch, 6.2 per cent.; (5) hemlock, 6.0 per cent.; (6) hard pine, 5.7 per cent.; (7) oak, 4.6 per cent.; (8) tamarack, 4.4 per cent.; (9) all others, 9.2 per cent. The percentages representing steam-road consumption were practically the same except that white cedar and Douglas fir were in reverse order. In the past over 75 per cent. of all wooden ties used in Germany were oak.

54. Size and Spacing.—The proper size and spacing of ties are functions of the condition of track and traffic. An easier riding track results from the use of smaller ties placed close together than from larger ties spaced farther apart. Therefore, the spacing should be considered as more important than the size. As the spacing is decreased, two advantages are obtained. First, the unit pressure of all track-materials is decreased and, second, the carrying capacity of the roadbed is increased correspondingly. The elements governing the spacing of ties, such as the character of the subgrade, kind and depth of ballast, axle loads, kind of wood, width of rail-base, whether tie-plates are used or are not used, drainage, etc., are so variable that it is hardly possible to follow any fixed rule for the spacing of ties. The minimum spacing should not be less than the width of track-shovels used. The usual spacing varies from 2640 to 3200 per mile or from 16 to 18 for a 30-ft. rail, or 18 to 20 for a 33-ft. rail. On sidings the spacing is from 14 to 16 per 30-ft. rail. Second-hand ties in sidings are usually spaced 18 per 30-ft. rail. Considering the United States and Canada, about 43 per cent. of all mileage has 16 ties, about 19 per cent. has 18 ties, about 14 per cent. has 17 ties, and about 5 per cent. has less than 16 ties, per 30-ft. rail.

The thickness of ties now in use varies from 6 to 8 in. In any case the thickness should not be less than 6 in. as the tie might be split by the spike. The width varies from 6 to 12 in. and the length from 8 to 10 ft. The 10-ft. length is used for bridge-ties and for track over marshy ground. About 47 per cent. of all track in America is laid with

6-in. by 7-in. by 8-ft. ties, 10 per cent. with 7-in. by 8-in. by 8-ft. ties, 10 per cent. with 7-in. by 9-in. by 8½-ft. ties, and about 6 per cent. with 7-in. by 9-in. by 9-ft. ties. Most railways now consider a size 6 in. by 8 in. by 8 ft. or less to be too small for use in track carrying heavy traffic. The size of ties used in Germany is from 8 ft. 2½ in. to 8 ft. 10¼ in. long, 9 7/16 to 10¼ in. wide, and 5½ to 6 5/16 in. thick.

55. Bridge-ties.—A common size of bridge-tie is 8 in. by 8 in. by 9 or 10 ft. A thickness less than 8 in. is seldom used because of the dap in the tie at each stringer, although the Seaboard Air Line uses a 6-in. by 8-in. by 9-ft. bridge-tie. The dap is usually ½ in. The spacing of the ties depends upon the size of tie and design of the bridge or trestle. The Lehigh Valley uses 8-in. by 8-in. by 10-ft. southern long-leaf yellow pine ties, spaced 16 in. center to center, on all pile and timber trestles. The Wheeling and Lake Erie uses 12 8-in. by 8-in. by 10-ft. ties or 10 8-in by 10-in. by 9-ft. ties, per 14-ft. trestle-bent. The Wabash uses the same size and spacing as the Lehigh Valley. On the Queen and Crescent 8-in. by 10-in. by 10-ft. bridge-ties are spaced 14 in. center to center with the 10-in. dimension vertical. The Chicago, Milwaukee and St. Paul spaces 8-in. by 8-in. by 10-ft. ties 12 in. center to center.

56. Renewals.—The actual cost of tie-renewals may be divided as follows: (1) the cost of the new ties distributed along the track; (2) the cost of removing the old tie and disposing of it (from 5 to 10 cts.); (3) and the cost of placing the new tie in the track (10 to 20 cts.). The last two items depend entirely on labor costs and bear a very important relation to the total maintenance expense. Taken together they are from 20 to 60 per cent. as large as the first item, depending on the kind of tie and ballast. The cheaper the first cost of the tie, the larger is the proportion of the last two to the first. The average cost of removing the old tie, placing the new tie and tamping is about 23 cts. per tie. The cost is less in gravel than in stone ballast.

The number of tie-renewals per mile of track per year depends upon (*a*) the kind of traffic and (*b*) the kind of tie, that is, the kind of wood and whether treated or untreated. A less percentage of undecayed wood can be allowed before renewing a tie on light-traffic lines, so that the same tie would be removed 1 or 2 years sooner on a heavy-traffic than on a light-traffic line. This may be offset by poorer drainage, and hence more rapid decay, on the light-traffic line. If oak ties lasting 8 years are used, the yearly renewals would be just half as numerous as if inferior ties lasting 4 years were used. In such a case, even though the inferior tie cost but half as much as the oak tie, two inferior ties would have to be placed for one oak tie. As the expense of placing ties of all woods is about the same, the actual cost of tie-renewals would be greater for the inferior tie under the conditions assumed. Besides the additional expense for renewals in the case of the inferior tie, the railway also has the disadvantage of unsettled track due to its being more frequently disturbed. It is practically impossible to get a newly placed tie at once as firmly bedded as the one replaced. The new tie may be of a different thickness than the old one so that when it is placed it will be a little high or a little low. In either case the result is an irregularity in the surface of the track. Even if the track is to perfect grade, the power of the tie to support the train-load without deflection will generally be different from that of the adjacent tie, due to a disturbance of the ballast beneath it while making the renewal. This makes a rough-riding track and adds somewhat to the wear of wheels and rails, and will continue to exist until the occasional tamping of the tie and the pressure from the loads have restored it to its normal condition. By using metal tie-plates and treated ties a longer life of tie will be obtained and individual renewals will be less frequent.

Besides the first cost of the tie and the cost of placing it in the track a tie-renewal often means some new spikes and an occasional tie-plate, or rail-brace. In some cases a slight value for material released, or value of old material, can be allowed. The best of old ties taken out of main track may be relaid in sidings, used for cribbing over wet places where mostly they will be under water, split and used for fence-posts, or used in construction-track. Those less sound may be used as fuel in making burnt clay ballast, or cut and used as fuel for section-houses, small stations, etc. Those which are too far gone for use in any other capacity are piled on the right-of-way and, after being inspected, are burned and the ashes afterward raked for scrap-iron. Where used for fuel the ties may be cut by a saw, or by a shearing-machine in which the blades are set about 1 in. apart to allow spikes to pass through without injuring the blades. Shearing-machines are generally operated by compressed air or hydraulic power and can cut timbers as large as 8 or 10 in. square.

When untreated ties without tie-plates are used, the yearly tie-renewals average from 250 to 350 per mile of main-line track. Many trackmen consider that the normal tie-renewals each year for first-class ties under moderately heavy traffic should average about two renewals per 30-ft. rail. The necessity for renewing a large percentage of ties during any one season is a certain indication of previous neglect or "deferred maintenance." Trackmen should be instructed as to the proper time for making renewals, proper manner of piling and seasoning, the proper place to use softwood, hardwood and treated ties, and where second-hand and cull ties may be used temporarily.

In Canada, from 1909 to 1913 inclusive, while the actual cost in dollars and cents of rail-renewals increased almost 13 per cent., the proportional cost of rail-renewals to total maintenance of way expenses slightly decreased. During the same period the cost of tie-renewals increased over

18 per cent. and there was a slight increase in the proportion of this item to total maintenance of way expenses. The tendency for the cost of tie-renewals to increase is due to the following:

1. The constantly increasing price of ties caused by the steady rise in price of timber as the supply decreases, and by the increased length of haul as the source of supply becomes more remote.

2. The use of the best grades of timber for other purposes, leaving inferior qualities to be used for ties.

3. Careless specifications and inspection, resulting in the acceptance of inferior material.

4. Increased mechanical wear of the tie under heavier traffic, resulting in rail-cutting and spike-killing the tie.

57. Single Renewals versus Renewals in Continuous Stretches.— There are two ways in which tie-renewals may be made: (1) single renewals or "spotting," (2) renewals in continuous stretches or "out of face." There are certain advantages to be derived from each method, but practically all railways use the method of single renewals in all but special cases.

The advantages of single tie-renewals may be stated thus:

1. There are always several sound new ties under each rail, making a stronger and safer average track.
2. A longer average life of tie is obtained, resulting in less waste of material.
3. Uniformity year by year of maintenance charges.
4. A better maintenance organization because the labor force is more nearly constant.
5. Track can be kept to more uniform gage.

The disadvantages of single tie-renewals are:

1. A continual disturbance of track with resultant irregularities of surface, the disadvantage being much greater where other fixtures such as paved street crossings, interlocking plants, etc., must be disturbed.
2. A probable higher renewal cost per tie.
3. The requirement of a large amount of time of the section force each spring in making tie-renewals at a time when the track badly needs general attention.
4. Right-of-way is littered each year with old and new ties.

The following advantages may be claimed for renewals in continuous stretches:

1. Labor cost is less and at the time of renewing ties ballast can be cleaned by using forks or screens.
2. Roadbed is disturbed less frequently, resulting in a more uniform support to the traffic.

The disadvantages of renewals in continuous stretches are:

1. For first year or two track is in better condition than by making single renewals. But from the time the renewals are made the condition of the track

steadily deteriorates until a time comes, which is just before renewal should again be made, when the track contains no sound ties and is unsafe.

2. Because of the inequality of the life of ties, even of the same wood, many ties which would last 1, 2, or 3 years longer would be taken out and wasted. Therefore, the average life of the ties would be shortened.

3. Track eventually develops irregularities of gage which it is difficult to remedy without placing a few new ties under each rail.

All things considered, the practice of single renewals is the best for ordinary track conditions. This does not mean that two or three adjacent ties should never be renewed together. On the contrary, if the condition of several adjacent ties is such that there is no more service in them it is most economical to renew them together. The labor cost of renewing two adjacent ties is scarcely more than that for renewing one tie. Also, where it is necessary to renew one tie at a rail-joint it is quite common practice to renew the one or two other joint-ties at the same time; the middle tie may also be renewed simultaneously, as it is the joint-ties and middle ties upon which gage and surface principally depend. Prior to about 1910, the practice on the Chesapeake and Ohio was to renew ties in continuous stretches.

In special cases such as the following it may be more desirable to make renewals in continuous stretches; (1) where paving or other covering must be torn up, as at street and highway crossings; (2) on short stretches of track under very heavy traffic; (3) at station-platforms; (4) at interlocking plants; (5) in narrow tunnels or narrow rock cuts; (6) on the inside tracks where there are more than two tracks; (7) where track is being reballasted; (8) on heavy-traffic lines where the life of rail about equals that of the ties or when renewing rails under heavy traffic.

58. Inspection and Requisitions.—A tie should never be removed from track until not another year of service remains in it. On the other hand, it is equally poor economy to leave badly decayed ties in track because they throw additional load on adjacent ties, more rapidly causing failure of the latter. The question of deciding just what ties present these conditions is one requiring much experience and judgment. On many railways it is left entirely with the section-foreman. Not infrequently the attitude of the foreman is to use up all ties on hand each season, irrespective of the fact that by so doing some ties are removed which had 1 or 2 years more service in them. The best method is to provide regular tie-inspectors whose duty it is to walk over the track and either personally mark all ties that should be renewed that season or check the reports of the section-foreman. The inspector then submits a requisition for the required number of ties, to the division engineer, division superintendent, chief engineer, or engineer of maintenace of way, according to the organization. On the Southern Pacific requisitions are prepared by the roadmasters after a personal inspection made in June of each year. On the Canadian Pacific the practice is to send a man, well versed in tie conditions, over each subdivision in the spring of each year. This man marks with a spot of red paint the ties he considers not good enough for another year's service, using proper judgment and taking into consideration the condition of adjacent ties. The ties so marked are replaced during the summer. If a section-foreman thinks some tie should be removed which has not been marked by the inspector he takes the matter up with the roadmaster who decides whether or not the renewal shall be made. The practice on the Frisco Lines is for the roadmaster each fall to walk over each section on his division, accompanied by the respective section-foreman. They count and mark with an adze the ties which in their judgment should be renewed during the next season, and make requisitons for new ties accordingly. On the Buffalo, Rochester and Pittsburgh Ry. all ties to be renewed in a season are marked by inspectors as soon as the frost is out of the ground in the spring. An abstract of the Instructions for Tie-inspection and -renewals of this railway is given in the following article. The business organization of some railways makes it necessary in the fall for the purchasing agent to have an estimate of the number of ties required for renewals the next spring. This necessitates an inspection and count in the fall, which comes so close upon the renewals made that summer, when all unserviceable ties should have been renewed, that but little idea can be formed of what the condition of the ties will be the next spring, 6 or 8 months later. For this reason a spring inspection, made just as short a time as possible before the work of renewal starts, is the best. On old railways an estimate based on the average renewals for a series of years previous will give better results than a fall inspection. On a few roads in the South tie-renewals are made twice a year.

Every division engineer, superintendent or other official whose duty it is to pass on tie-requisitions should give them close attention and check them systematically by a personal inspection of a section of track. If the requisitions are granted too freely, there is a tendency for the section-foremen, on railways not having inspectors to actually mark all ties to be removed, to take out ties which still have a year or so of service left in them. On the other hand, if requisitions are invariably cut down without a proper investigation many worthless ties will be left in the track, reducing its strength. Some railways forbid the removal of any tie having more than 4 in. of sound wood left under the rail. In no case should ties be removed without orders and when taken out they should be piled by the track, but should not be burned or removed until inspected by the proper authority to see that no serviceable material will be wasted.

59. Instructions for Tie-inspection and -renewals, Buffalo, Rochester and Pittsburgh Railway.[1]

1. To secure uniform practice, prevent the removal of ties from the track before their safe service is past, and at the same time properly distribute renewals, hereafter, in all tracks, ties for renewal will be marked by inspectors reporting direct to Division Engineers.

2. The first thing in the spring, when the frost is out of the ground, inspectors, after conferring with roadmasters, will inspect 1 mile of main track on each section, in order to allow section forces to begin renewals. They will then drop back and complete the inspection, both in main tracks and sidings. Inspectors will make a daily report to the division engineers and roadmasters on proper form, showing the number of ties marked for renewals in the main track between each mile-post, and the number of cross-ties and crossover sets marked for renewals in each siding, giving the siding numbers.

3. Section-foremen must in all cases accompany the inspectors over their sections while inspection is being made. For 19— renewals, one heavy white mark must be placed on the rail above each tie to be renewed, this mark to be placed on the ——— side of the rail. Inspectors must keep a book-record of all inspection, to be used from year to year for comparison

4. There will be two standards for marking renewals. Case 1, where track is not to be disturbed; Case 2, where track is to be raised off the old bed. In the latter, ties will be placed while the track is being raised, thus placing them all on the new bed. In the former case, the ties will be dug in.

5. Inspectors must be provided with standard inspection-picks, paint-brushes, and necessary white lead paint.

6. Inspectors will be given a statement showing track which is to be raised on each section, also track where new steel is to be laid and reballasted.

7. Every tie which, apparently, is not good or which shows signs of decay and failure must be inspected with the pick.

8. In determining the necessity for replacing a tie, its condition as to decay and wear, traffic carried, its position in track, kind of timber, condition of neighboring ties, weight of rail, and tie-plates, must all be considered.

9. Main track not to be raised—Ties spotted in—Case 1.

Ties must be inspected for condition of timber by driving the pick into each side adjacent to the rail seats, both near the bottom and near the top face, below the sap line. The pick must be driven into the ties toward the center and must be drawn with as little prying as possible. Ties must not be tested on the top, with exception of making tests for decay around tie-plates and spikes, and in making these tests the ties must not be mutilated more than absolutely necessary. To test a tie for strength, one end of the pick should be inserted under the end and the pick used as a lever. If a tie is broken under the rail-seat, this method will usually determine it.

9*a*. If two ties with 1 year's safe service are adjacent, one must be removed; and a group of ties with only 1 year's safe service must be so renewed as to leave each doubtful tie with one good neighbor.

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[1] Abstracted from Bulletin 173, American Railway Engineering Association.

9*b*. Sap-rot alone is not to condemn a tie for service.

9*c*. A rail-cut tie is not to be removed unless the rail is cut into the face more than three-fourths of an inch. On curvature where, through repeated rail removals, ties are necessarily adzed more or less for the new plate, when a tie is so rail-cut as to weaken it for the service imposed it should be removed from the track and saved for siding-renewals, if the timber is sound. On tangents where a good tie is cut three-fourths of an inch with rail-wear or adzing, it should be protected with tie-plates against further cutting.

9*d*. In case ties are spaced too far apart or where a large hewed tie is removed and replaced with a smaller tie, an extra spacer may be inserted as the judgment of inspectors may decide.

9*e*. Very careful attention must be given to inspection of red oak and pin-oak ties, as such ties usually rot from the center, leaving a hard shell which can be detected only by careful inspection.

9*f*. Where track is subject to heaving and where shimming is necessary, care must be taken to insure enough good, sound timber for spiking and bracing, and careful attention must be given to inspection of ties through road crossings, station-platforms and other places where the ties are covered and liable to be overlooked by the section-foremen.

10. Main track which is to be raised during progress of resurfacing and reballasting out of face—Ties placed when track is being raised—Case 2.

In addition to reballasting track where new rail is laid, it is the intention to resurface out of face a part of the main track on each section each year, and make sufficient renewals in such tracks to last 2 or 3 years, depending upon conditions, without being disturbed for renewals during that time. Inspectors will, therefore, make a liberal inspection of such strips of track, testing the ties as in Case 1 for decay, but removing all ties that will not last more than 2 years, and where new steel is laid, no bad ties must be left under the joints. In making renewals in this case, some fairly good ties may be taken out, in which case they should be carefully sorted and piled, to be picked up and distributed for siding-renewals.

11. A lower standard of inspection must be used for mine lines and sidings, especially for standing tracks in yards, where no tie must be taken out until its safe service is past.

12. In passing tracks care must be used to see that ties around turnout curves are in good condition.

13. In main tracks and sidings, where track is not to be lifted, section-foremen must renew only the ties that are spotted by the inspectors, and in case they find ties which, in their judgment, should be renewed, they will so notify the roadmasters and the inspectors will be sent back to make a reinspection. Where track is to be raised, the foremen will renew ties marked by the inspectors and may remove any unmarked ties which, in their judgment, should come out, such ties to be marked with a cross "X" on top surface and laid aside for examination by the inspectors.

14. The inspection of ties by an independent inspector does not relieve the roadmasters and section-foremen of responsibility for the safety of their track.

15. Inspectors will inspect all switch-ties in accordance with the above, except that in case a switch or crossover set is more than one-half decayed, requiring

renewals, a new set should be put in. The old ties taken out, which are fit for use, must be saved and used for patching other sets.

16. As all main-track cross-tie and switch-tie renewals since 1910 have been made with treated ties, roadmasters, foremen and inspectors must give these ties careful attention and report promptly any ties showing signs of failure from any cause whatever, giving location, kind of timber, year placed in track, etc.

17. After tracks have all been gone over and inspected, the inspectors will spend their time checking renewals and marking any ties that were missed by their first inspection. They should also carefully examine all ties taken out by foremen which were not originally marked, and see that all usable ties taken out of the track from any cause whatever are properly sorted and redistributed for siding-renewals. Inspectors must give careful attention to all features of track work as they go over the line from time to time, especially in connection with tie-renewals, and report promptly to their superior officers any defective practice coming to their attention. Our instructions prohibit foremen from striking picks or other tools in the ties when drawing them into the track, and inspectors should give this matter careful attention; also adzing, spiking, etc.

18. All concerned should realize the great importance of tie-renewals and the necessity of making sufficient renewals properly distributed through all tracks to carry heavy traffic. At the same time the increasing price of ties must not be overlooked. Therefore, no timber should be destroyed until its safe life has passed, either in main track or sidings.

60. Specifications for Ties.—By purchasing ties under careful inspection and carefully drawn specifications a better quality of material will be obtained, resulting in an ultimate reduction of cost. The following is an abstract of the tie-specifications of the St. Louis and San Francisco Railroad:

Quality of Ties and Workmanship.—All ties must be well and smoothly hewed or sawed out of straight growing timber of specified dimensions, out of wind, sawed ends, with straight and parallel faces. All ties must have bark entirely removed before being delivered on the Company's ground.

Ties shall be free from splits, shakes, loose or decayed knots or any other imperfection which may impair their strength or durability.

Cypress ties containing 85 per cent. or more of heart-wood will not be treated. Cypress ties containing a greater percentage of sap-wood will be treated.

Long-leaf heart yellow pine shall show one side all heart; the other side and two edges shall show not less than 75 per cent. heart measured across the face anywhere in the length of the piece.

At the time of delivery, ties of the red-oak family shall not have been cut or trees felled more than 6 months, the pines not more than 1 month, and all other kinds of ties that are to be treated, not more than 3 months.

First-class Ties—Size.—Track-ties shall not be less than 8 in. wide in body, shall not have a face of less than 7 in., and shall not be less than 6 in. thick, nor less than 8 ft. long. A variation in size will be permitted of 1 in. over in thickness, 2 in. over in width, and 1 in. over in length.

Second-class Ties—Size.—Track-ties conforming to the above specifications except as to size, will be accepted as second-class ties to the extent of . . . . . per cent. of the entire order, provided they have not less than a 6-in. face, and are not less than 5½ in. thick nor less than 8 ft. long.

DELIVERY.—Only one class of ties shall be loaded on a car, unless otherwise specified.

Ties delivered on the premises of the Railroad Company shall be piled not less than 10 ft. nor more than 50 ft. from the nearest rail of any siding, and not less than 20 ft. nor more than 50 ft. from the nearest rail of the main track. Ties shall not be piled below the grade of track. Each pile shall contain either 25 or 50 ties and shall be built with 2 ties on the ground and above in alternate courses of 7 and 2. Three feet of space must be left between piles for easy inspection. Each pile must be plainly marked with the owner's name and date when piled. Sawed ties must be piled separately from hewed ties.

If ties are to be treated, the various kinds of timber shall be piled separately.

All rejected ties must be removed from the Company's right-of-way within 10 days after notice is given.

61. Conditions Affecting the Life of Ties.—In speaking of the life of ties, what is really meant is the main-track life. Ties in sidings and yards are not considered because the ties used there are second-hand or culls; although economy would often result if a better grade of ties were used, particularly in yards handling heavy traffic.

A tie ultimately fails from one of two causes, namely, (*a*) decay, or (*b*) mechanical wear. The power of a tie to resist these destructive elements very largely governs the character of the track-construction. In general, any wood, hard or soft, which decays rapidly is but little benefited by the use of tie-plates if it is used untreated. On the other hand, soft woods that resist decay well, such as cedar, should be provided with tie-plates whether treated or untreated. Hard woods which resist decay well but eventually fail from decay should be used treated.

There are many conditions which affect one way or the other the life of a tie. Because of the lax system of making renewals on many railways, but few authentic records are available. Besides the varying climatic, track, and traffic conditions, the quality of ties of the same wood varies so that under identical conditions ties of the same wood have different lives. On the Atchison, Topeka & Santa Fe Ry. it has been observed that the life of ties received at the same time and cut from the same forest varies from 1 to 5 years. The ideal condition would be for all ties in the same track to have a uniform life. This is far from being realized. An approach can be made to it, however, by carefully inspecting and grading new ties and by giving them a preservative treatment. The life of ties of a certain wood is more uniform if the ties are treated than if untreated. Ties should not be put in track in a haphazard manner, but ties of each kind of wood should be placed where they are best fitted for the service required. The Louisville and Nashville R. R. uses red-oak ties which have a life of 4 years untreated. On tangents, the ties treated with zinc chloride are used without tie-plates. It is estimated that by treating the ties in this way and using no tie-plates their resistance to decay will about equal their resistance to mechanical wear, so that failure will result from a combination of the two causes. On curves, treated ties without tie-plates would fail from mechanical wear, but if tie-plates were used on ties treated with zinc chloride ultimate failure would result from decay rather than from mechanical wear. Though a much more expensive treatment, creosoting will give a longer life than zinc chloride and it is used for treating all ties on which tie-plates will be used. By this combination failure will probably result from mechanical wear, but if it does ultimately result from decay, it will be prevented as long as possible. The Santa Fe uses oak ties under heavy traffic on curves, long-leaf pine and gum under heavy traffic on tangents, and softer woods for less important lines.

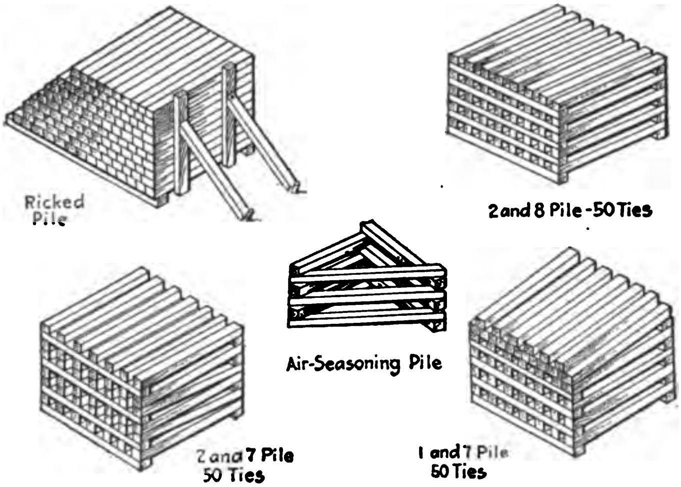
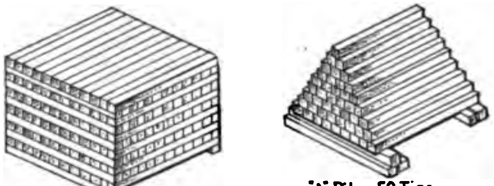


FIG. 24.—Different methods of piling untreated ties.

Ballast that is drained insufficiently holds moisture around the tie and shortens the life of the tie by hastening decay. Better drainage of the interior of ties in well drained ballast might be secured by boring spike-holes completely through the tie. Because of the greater stresses in the track on curves, ties do not last as long on curves as on tangents. This is in part the result of the unbalanced pressure of fast and slow trains against the outer or inner rail, which tends to push the outer spikes horizontally away from the track, thus enlarging the hole and reducing the holding power of the spikes.

The age of the tree and the season in which it is cut affect the properties of the tie. Young wood contains a much larger percentage of albumenoids than does mature wood. As it is the albumenoids upon which fungi largely feed, young wood decays more rapidly than mature wood. The best hardwood timber is obtained from trees of rapid growth, indicated by broad, regular, annular rings due to favorable conditions of soil and light, which necessitate rich, warm soil and open forests. Sound, mature, second-growth timber is nearly or quite as good as the first growth. The best wood from coniferous trees is obtained from trees of slow growth, indicated by narrow annular rings, which would necessitate comparatively poor soil, high altitude, and dense forests. In woods of the same species the heaviest wood is the most durable. The best time for felling tie-timber is in the winter, because the wood contains less sap and seasons more slowly, so that there is less checking. Timber cut when the sap is at rest, either in winter or summer, is more durable than that cut when the sap is moving.

The effect of the period of seasoning upon the life of ties is discussed in Chapter VII. Seasoning, itself, is affected by the way in which the ties are piled. Untreated ties should be piled in such a way as to allow free circulation of air around each tie. There are several methods of doing this, four of which are shown in Figure 24. Some railways also pile ties treated with zinc chloride in this manner. The more common practice, based on the belief that ties treated with zinc chloride check by too rapid drying if piled in open piles, is to pile them in solid piles similar to those used for creosoted ties. The ricked pile (Fig. 24), though used frequently for storing large quantities of untreated ties, is objectionable because it prevents or retards air-seasoning. Figure 25 shows two methods of piling creosoted ties. Piles of ties should be not less than 10 or 15 ft. from the nearest rail. Treated ties should be handled only with tie tongs because of the danger from poisoning if handled with bare hands.



Solid Pile-134 Ties, Layers Laid Alternately.

"A" Pile - 50 Ties, Pitched.

FIG. 25.—Methods of piling treated ties.

Certain woods, such as the red-oak family, gum, beech, chestnut, birch, etc., check or split badly during seasoning or after being treated. These cracks are objectionable because they permit water to reach the interior of the tie, causing rapid decay and a liability to split when the spikes are driven.

For a number of years the practice of many European railways has been to drive S-shaped pieces of strap-iron into the ends of the ties to prevent checking. After being bent to shape, the S pieces are 4 to 5½ in. long and 1½ to 2 in. wide. The strap-iron is about 1 in. wide. Several

American railways which use large numbers of ties, are now following this European example. The Santa Fe uses S irons in the ends of all hardwood ties and in ties of other woods that are liable to check. During the past 5 years the Austrian and Hungarian State Railways have adopted the use of wooden dowels to prevent splitting of the ties. The dowels are about 12 in. long and 1 in. in diameter. Two holes are bored through the thick dimension of the tie, 4 to 6 in. from each end. The dowels are then inserted and the projecting ends are sawed off. On the Hungarian State Railways, the cost of two dowels, boring holes and placing dowels in one tie was about 5 cents.

It is generally considered that when ties are to be used untreated, hewed ties are superior to sawed ones, other things being equal, because the hewing closes the pores of the wood and leaves a smooth surface which does not absorb water. This means that only one or two ties can be made from a tree, while if the ties are allowed to be sawed, larger timber can be used, more ties can be obtained from a section, and lumber can be obtained as a by-product. Untreated, sawed ties decay more rapidly because the cut cannot be kept parallel to the grain of the wood, particularly if the stick is a little crooked, and a larger end area of the fiber is exposed than in hewed ties. The objection that the rough surface left by the saw absorbs water more readily than the glazed surface left by the axe can be overcome by the use of a planer. Sawed ties are to be preferred for treating as they take the treatment more readily than if hewed.

Split ties check badly because the heart is exposed on one face. This face should always be placed downward in the track. Crooked ties should not be used because they rock in the ballast. Ties with the bark on should always be stripped before being placed in the track because the bark soon loosens and will retain water around the tie. As the loose bark offers but little friction to the tie the track is likely to shift.

The mechanical wear of the tie is due to the cutting of the base of the rail or the tie-plate into the surface of the tie, frequent redriving of spikes, and repeated tamping of the tie. Rail-cutting of the tie is aggravated by the use of sand by locomotives and by gritty ballast.

Decayed ties removed from the track should be inspected and burned or otherwise disposed of as soon thereafter as possible in order to prevent the spores or seeds of fungi from spreading to sound ties.

62. Tie-records.—When ties were plentiful and cheap there was no great need for keeping a close record of their life, and on most railways none was kept. Conditions have changed. The present high cost and the increasing use of treated ties makes it imperative that a systematic, reliable, and uniform record of tie-performance be kept by each railway. The American Railway Engineering Association recommends the use of the following five standard forms for this purpose:

Form M. W. 300, "Foreman's monthly tie-removal report."
Form M. W. 301, "Statistics of cross-tie renewals."
Form M. W. 302, "Comparison between different kinds of wood."
Form M. W. 303, "Life record of ties."
Form M. W. 304, "Statistics of treated ties."

The real difficulty in obtaining the desired information is to get exact statements from the section-foremen, the men actually handling the ties. Form M. W. 300 is prepared especially for this purpose and must be filled out and sent in monthly by each foreman. This report shows the name or number of the division, section number, number of ties removed, the year they were put in, the kind of preservative treatment, the kind of wood, and the cause of removal.

The four other forms, M. W. 301–304, when properly filled out give the following information: (1) Length of division. (2) Length of all main track. (3) Average number of ties per mile. (4) Average number of tie-renewals per mile. (5) Per cent. of renewals to number in track. (6) Total number of ties renewed. (7) Kinds of timber used. (8) Number of each kind renewed. (9) Cost of new ties in track. (10) Temperature range and approximate rainfall. (11) Dates when old ties were laid and removed. (12) Per cent. of curved main track to total main track. (13) Per cent. of main track tie-plated. (14) Kind of ballast and percentage of each. (15) Weight of rail. (16) Per cent. of treated ties to total number of ties. (17) Antiseptic used. (18) Amount injected per cubic foot. (19) Average cost of treated ties at point of distribution. (20) Average cost of untreated ties at point of distribution. (21) Average life of treated ties. (22) Average life of untreated ties. (23) Total cost of tie-renewals per mile of main track. (24) Gross tonnage of traffic per annum. (25) Maximum weight of locomotives. (26) Number of ties renewed in side-track. (27) Per cent. of ties renewed in side-track. (28) Number of old main-track ties put in side-track.

63. Marking Ties.—In order to know how long a tie has been in track it is necessary to mark the tie in some way to indicate the date when the tie was first put in the track. The earliest method of doing this was to cut a notch in one of the upper edges of the tie, in a certain position to indicate the year. The New York Central & Hudson River R. R. still does this for untreated ties. Another method, which was used as early as 1875 by the Atchison, Topeka & Santa Fe Ry., is to stamp or brand the tie with a die and sledge, or branding hammer. The objection to both of these methods is that the notches or brands may become obliterated before the tie is removed and the record will thus become lost. The galvanized dating nail has now become the standard means for marking. These nails are heavily galvanized, are 2½ in. long, and have a ⅝-in. head upon which are stamped two figures indicating the year the tie was laid or letters indicating the kind of wood. They are driven on the upper face of the tie a certain distance, differing for each year, from the "line" side of the track. In order to avoid mistakes they should be driven by the foreman immediately after the tie is placed in the track. The line side of single track is designated variously as being the south or east side, by the Philadelphia and Reading Ry.; the right-hand side, going north or west, on the Pennsylvania Railroad; the right-hand side on tangents, going with the increase in the mileage, and the inside of curves, on the Frisco Lines; the south and east side, on the Canadian Pacific Ry. For two or more tracks the line side of each track usually is taken as the right-hand side going in the direction of traffic. The distance from the base of a standard 85-lb. rail to the lined end of an 8-ft. tie is 16 in. The ordinary galvanized dating nail, though the best method now in use for marking ties, is not entirely satisfactory as after being in the track 10 or 12 years the figures may become illegible. Also copper dating nails have been tried.

64. Cost and Life.—The average cost of all untreated ties purchased by steam-railways in Canada in 1913 was 42 cts. The highest price paid was 85 cts. for maple and elm, but these represented only 0.2 per cent. of the total. The average cost of ties of the various woods was as follows:

1.	Maple and elm	85 cts.	8.	Ash	43 cts.
2.	Oak	69 cts.	9.	Tamarack and birch	42 cts.
3.	Beech	62 cts.	10.	Jack-pine	40 cts.
4.	Hard pine, chestnut and cherry	55 cts.	11.	Hemlock	38 cts.
5.	Western larch	52 cts.	12.	Douglas fir, spruce, red cedar	33 cts.
6.	Red pine	45 cts.	13.	Western hemlock	31 cts.
7.	White cedar	44 cts.	14.	Western spruce	26 cts.

There were 534,592 poles purchased in Canada in 1913, at an average cost of $2.22 each. The average cost according to length was 20 to 25 ft., $1.36; 26 to 30 ft., $2.53; 31 to 35 ft., $3.89; 36 to 40 ft., $5.91; over 40 ft., $9.16.

If the tie is to be treated, the final cost of the tie will be the first cost, plus the cost of treatment. Prior to 1915 the cost of creosote was from 8 to 10 cts. per gallon, which weighs 8.6 lb. at a temperature of 38°C. and 1.03 specific gravity. The cost of handling the tie at the treating plant and applying the treatment is from 5 to 10 cts. a tie. Hence, the cost of the treatment would be from 5 to 10 cts., plus the cost of the creosote injected. Sixteen railways in the United States reported the actual costs of treatments in 1913, including labor, material, fuel, handling of ties, and interest and depreciation in the case of company plants, as follows:[1]

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[1] Vol. 15, Proceedings, American Railway Engineering Association, page 739.

Straight creosote treatment administered at a plant operated by the railway company, average of six railways, 27.6 cts. per tie; straight creosote treatment under contract, average of three railways, 28.9 cts.; zinc chloride, company plant, average of three railways, 10.4 cts.; zinc chloride, contract, average of two railways, 15.2 cts.; Card process, company plant, average of two railways, 17.5 cts. Were it not for the failure of a tie from mechanical wear, its life could be increased to 20 or 30 years by a heavy treatment of creosote. Since the life is limited by mechanical wear in any case, it would be a waste of money to spend one cent more for treatment than that necessary to preserve it from decay during its mechanical life. The amount that can be economically added to the first cost of the tie to increase its life a certain length of time can readily be computed by the method explained in Arts. 74, 75 and 76. The real difficulty is in estimating the life of a given tie and whether failure will result from decay or from mechanical wear.

In Europe wooden ties cost from two to three times what they do in America and the railways are justified in using the heavy treatment that they do. Consequently they get a longer average life of tie. Mr. H. F. Weiss gives the following list of the average life of treated ties for different countries:[1]

Germany, Prussia, and Austria	18.5 years.
France	17.5 years.
Great Britain	16.0 years.
Switzerland	15.2 years.

The average life of untreated ties on 230,000 miles of railway in Canada, the United States, and Mexico is about 7.8 years, and the average cost is 76.1 cts. The average life of treated ties is about 13.8 years, and the average cost is $1.031.[2]

The Grand Trunk Ry. uses cedar ties from Quebec, costing 41 cts., and oak ties from Kentucky, costing 58 cts. The average life of the cedar ties is about 8 years, and that of the oak 12 years. The Canadian Pacific Ry. uses untreated cedar, tamarack, jack-pine, hemlock and fir. The Southern Pacific R. R. uses redwood and fir, all treated on main-line track. Over 8,000,000 Burnettized ties are in use in that company's tracks. The average life of untreated oak and yellow pine on the New York Central R. R. is about 8 years and the cost is from 80 to 90 cts.

Several railways have discontinued keeping a record of each tie because of the difficulty of obtaining reliable reports from the section-foremen. To take the place of individual tie-records these railways now maintain short test-sections of track. A number of ties of each wood or treatment being used by the railway are installed in the test-section and are inspected at regular intervals by the company's engineers. It is believed that in this way much more reliable data as to the actual service of the ties will be obtained. The Burlington has at least one test-section of 1,000 ties on each of nineteen operating divisions. In all, some 26,000 ties are under the close observation of competent engineers of this company. The Santa Fe has the most comprehensive system of test-sections of any railway. The test-sections on this railway consist of one section-foreman's section on each superintendent's division. Other railways which have recently installed tie-test sections of track are the Atlantic Coast Line; Chicago, Milwaukee and St. Paul; Lake Shore and Michigan Southern; Missouri Pacific; and Pennsylvania.

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[1] 1913 Proceedings, American Wood Preservers' Association, page 80.

[2] Vol. 15, Proceedings, American Railway Engineering Association, page 746.

Examinations made by the engineers of the United States forest service on a test-section of track installed in 1902 on the Gulf, Colorado and San Francisco Railway, in Texas, showed that under conditions existing there the life of untreated ties without tie-plates was, for loblolly-pine and hemlock, 1.5 years; tamarack, beech and short-leaf pine, 2.5 years; long-leaf pine and red oak, 3 years; Spanish oak, a little over 4 years. (For average life of ties of different woods see also Art. 53.)

CHAPTER VI

SUBSTITUTE TIES—ECONOMICS OF TIES

65. Substitute Ties.—Any tie other than a wooden tie is spoken of as a substitute tie. All substitute ties so far designed can be classified as (*a*) composite—the essential parts of which are composed of two or more materials; (*b*) concrete—the essential parts of which are composed of concrete, plain or reinforced; and (*c*) steel—the essential parts of which are composed of steel.

The substitute tie has come into existence as a result of the increasing difficulty of securing and the increasing cost of good wooden ties. With but one or two exceptions all substitute ties are still in an experimental stage on American railways. Nevertheless, the substitute tie is a very important consideration in modern track-construction. Railways in the United States first commenced to experiment with steel ties about 1900, but at that time the steel tie was by no means new in railway-track. In 1864 a steel tie was invented by Vautherin, a French engineer, and since about that date steel ties have been used in Germany in constantly increasing numbers until in 1914 about 40 per cent. of the total railway mileage was on steel ties. Besides being used in Germany, metal ties have been used extensively in the Netherlands, France, Belgium, Switzerland, India, Mexico, and several countries of Africa and South America. From 5 to 10 per cent. of the world's railway mileage is laid with them. The design used in foreign countries follows two general forms, a rolled or pressed trough section or a metal plate or casting connected transversely in pairs by tie-rods. The majority of the steel ties designed in the United States have followed these patterns, but the most successful one is of a different design. Since 1900 the use of substitute ties has slowly increased in the United States until in 1915 about 1.0 per cent. of all ties in main track were substitute ties. Most of these were on one road.

The success of any substitute tie fundamentally depends upon three requirements; (1) cost of the tie, (2) the power of the tie to withstand the destructive forces of traffic, which tend to break the tie in two, to crush and shatter it, to pound it out of surface, and to shift it out of line, (3) the character of the rail-fastening. The failure of most concrete ties has resulted from the ties not meeting the second requirement, while steel and composite ties have failed about equally from (2) and (3). Derailments cause much more injury to substitute than to wooden ties. A successful rail-fastening must meet the following three requirements: (*a*) The fastening must consist of the fewest possible number of parts and must securely clamp together the rail and tie. Complicated fastenings invariably work loose and clatter, and are difficult and expensive to renew. (*b*) It must be of such a design as to allow a variation in gage and to take different widths of base of rail. (*c*) It must be capable of being insulated.

Between the years 1909 and 1914, 34 different designs of substitute ties, most of them patented, were placed in American track, being distributed among some 40 railways. When these were first tried it was thought that they could be spaced wide apart, similar to the European and Mexican practice. Experience shows that this cannot be done. The spacing is usually 18, 19 or 20 per 33-ft. rail.

66. Steel Ties.—The manufacturers of steel ties claim the following advantages for steel ties over wooden ties: (*a*) longer life; (*b*) reduced rail wear; (*c*) a reduction in the amount of labor required for maintenance; (*d*) superior track due to less frequent disturbances for tie-renewals, a more permanent gage, a firm grip of the rail-fastenings at each tie upon the rail, and that the efficiency of the tie for holding the track is practically 100 per cent. during the entire life of the tie; (*e*) an ultimate economy in rolling-stock repairs and general maintenance work.

Most of the ties tried have not justified several of these claims. Even should a tie be found which had all these advantages they would be offset to a considerable extent by the much higher first cost of the steel tie. Nevertheless the steel tie has come to stay and the development of satisfactory designs is but a matter of time. No one design can meet all conditions. A heavy section is required for heavy traffic, and a light section for light traffic. To meet this requirement the Carnegie steel tie is now manufactured in several different weights. Many railways, considering steel ties too expensive for ordinary use, are using them extensively for renewing switch-ties, where they offer marked advantages in permanency of gage and a minimum disturbance of switch and interlocking connections. Many of the ties tried have been very noisy due to the steel parts working loose and clattering. The experience on some roads has been that where broken stone ballast is used with steel ties it gives better results if the stones are smaller than those generally used with wood ties. On the Bessemer & Lake Erie R. R. the practice followed for some time was to use steel ties for making individual renewals of wood ties when renewal became necessary. It was found that this shortened the life of the adjacent wood ties. This was thought to be due to the fact that the steel tie, being shallower than the adjacent wood ties, forced the latter to carry more than their proper proportion of the load.

Steel ties injured by derailments can often be straightened and used again. In any case the scrap-value of steel ties is considerable while that of wood ties is little or nothing.

67. Carnegie Steel Tie.—The only substitute tie being used in considerable numbers in the United States and which can be considered as having passed the experimental stage, is the Carnegie steel tie. Even in this design a number of changes have been made from time to time since its first introduction about 1900. The first ties rolled were of an inverted trough section. In 1900 the Bessemer & Lake Erie R. R. installed 750 of these, weighing 199 lb. each. The present I beam section was first rolled in 1904. This is a simple unsymmetrical I beam with a base almost twice the width of the top. The section first rolled weighs 20 lb. per linear foot and is known as the M-21 section. It is 5½ in. high and has a 4½-in. top flange and 8-in. bottom flange. Over 1,000,000 of these ties are in service on the Bessemer & Lake Erie Railroad, and in 1914, 87 per cent. of the double-track main line between North Bessemer and Conneaut Harbor, a distance of 141 miles, was laid with these ties. In some cases the M-21 section has proved to be too light and the web has buckled under the rail. A heavier section, weighing 27.75 lb. per foot and known as M-28, now also is being rolled. This section is 6½ in. high and has a 5-in. top flange and 10-in. bottom flange. It is shown in Fig. 26. In both sections the rail is fastened to the tie by bolts passing through the upper flanges of the tie and through steel clips bearing against the top of the rail-base. The rail may also be secured to the tie with a wedge-fastening. The rails rest on tie-plates

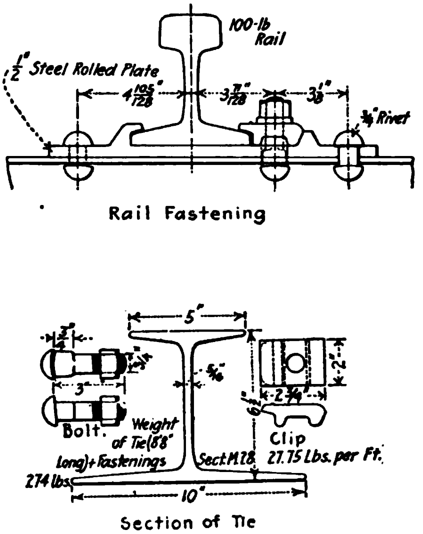

FIG. 26.—Carnegie steel tie—heavy section.

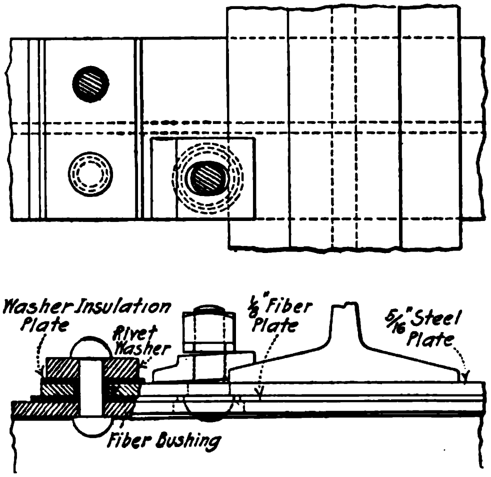

FIG. 27.—Method of insulating Carnegie steel tie.

which are made in several patterns, as are also the rail-clips. The fastening can be insulated, as shown in Fig. 27, and where used with track circuits has given no trouble. Ties originally installed without insulation can be insulated in the track by making some slight changes in the rail-fastenings. Different types of clips and tie-plates are shown in Figs. 26 and 27. The ties are 8 ft. 6 in. long and are punched for two weights of rail. Better to resist movement in the ballast, the tie can be obtained with the bottom flange crimped or bent down ¾ in. on each edge for a distance of 1 ft. on each side of the rail. Two light sections called M-25 and M-24 are rolled for use where imbedded in concrete, as in street-railway track.

68. Universal Steel Tie.[1]—This tie, shown in Fig. 28, is a rectangular trough or channel 8 in. wide, 4 in. deep and 8 ft. long. The bottom of the channel on each side of the rail has a slot 3⅝ in. wide and 3¼ in. long. The metal from the slot is bent up vertical to form guides, inside of which a wooden block is placed. The rail-fastening consists of an L-shaped clip, the long shank of which extends vertically downward and projects 3⅝ in. into the ballast below the tie. This is intended to prevent a lateral motion of the track. The vertical leg of the other clip is only long enough to extend to the bottom of the tie. The two clips are bolted together through the two turned up guides and the wooden block. The tie can be satisfactorily insulated. The projection of the clip into the ballast makes the tie very hard to line when the track gets out of line. The wood blocks decay rapidly and require frequent renewals. In Feb., 1911, 99 of these ties were installed on the New York Central & Hudson River R. R. In 1914 they were reported as still in service, the rail-fastenings holding well, the insulation, which had already been renewed once, as being satisfactory to the signal department, the wood blocks as badly decayed and the tie as being unsatisfactory in high-speed tracks.

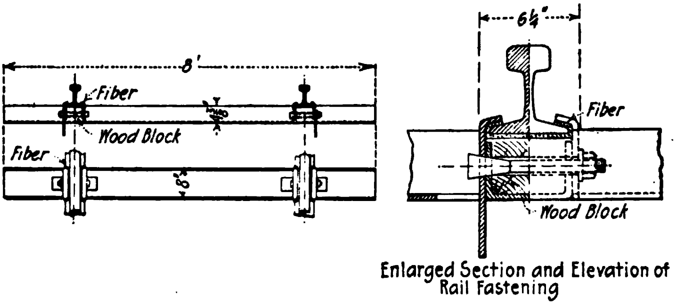

FIG. 28.—Universal steel tie.

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[1] From Vols. 13, 14, 15 and 16, Proceedings, American Railway Engineering Association.

During 1913, 192 of these ties were installed by the Atchison, Topeka & Santa Fe Ry. Some of these were first placed at the foot of a 1 per cent. grade on a 2° curve. Traffic in both directions was fast. It was soon found that vibration and the wave motion of the rail caused the broken stone ballast to work out of the channels and keep the shoulders loose. The line and surface were not at first affected, but the ballast was pounded into the roadbed more than with wooden ties. This pounding eventually wore the stones smooth and after this occurred there was trouble in maintaining alignment. The ties were then removed and placed in track at a point where the wave motion was not so great. In 1911 the Chicago, Burlington & Quincy R. R. installed 100 of these ties in a freight-running track at Chicago. In 1914 they were reported as being satisfactory, showing no wear but corroding slightly. Ninety-eight of these ties were installed by the Pennsylvania Railroad in 1910. The cost of maintenance was about three times that of adjacent track with wood ties. They were unsatisfactory and all were removed in 1913. The section used was considered not strong enough, as many ties broke under the rail-seat. Since 1911, 100 of these ties have been in track on the Pittsburgh & Lake Erie R. R.

69. Other Steel Ties.—Other steel ties, some of which are in track on various railways are the Baird, Boughton, Coffman, Hanson, Kimball, Maxey, Cast Steel Tie of the Metal Tie Co., Morgan, McCune, Rohm, Shane, and Seitz. These vary greatly in design. Most of them have been used in numbers ranging from 10 to 50 and not over 100 of any one have been used on steam-roads. Several have proved a failure. Others are giving satisfaction. The Morgan Steel Tie is rolled from old rails and has a section somewhat similar to the Carnegie tie. The section of the Shane Steel Tie is a rectangular trough in which the base projects about 2 in. beyond each web. The rail is carried in chains which are bolted to the webs.

Steel ties have been successfully used in mines, around industrial plants, and in construction-track. The section used for such purposes is an inverted trough, in some designs double, and is from 2 to 7 in. wide, ½ to 2¼ in. high, and weighs from 2 to 9 lb. per foot. In ties of this kind there must be no loose parts that can be lost and the rail-fastening should be a part of the tie.

70. Steel Ties on the National Railways of Mexico.—Steel ties have been extensively used in Mexico for many years. In 1909, 321 miles, constituting practically the entire system of the National Railways of Mexico, were laid with steel ties. The type used is illustrated in Fig. 29. The life of these ties is said to be from 25 to 35 years. Their weight is about 125 lb. each and their cost in 1909 at Vera Cruz was $2.25 in gold per tie. The design is taken from that of the Post steel tie invented by Mr. Post of the Netherlands State Railways. The experience of the railway has been

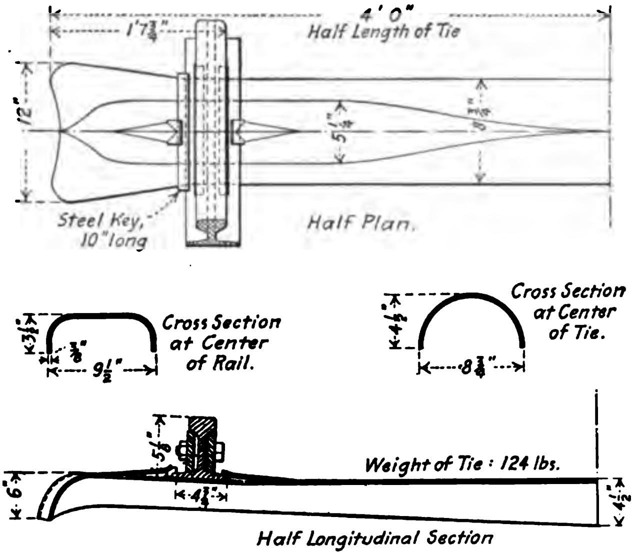

FIG. 29.—Steel tie of the National Railways of Mexico.

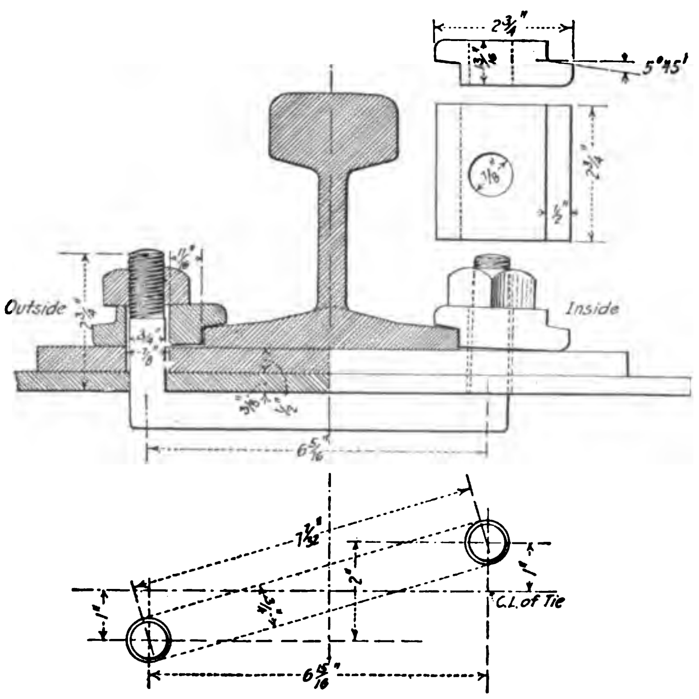

FIG. 30.—Recent improvement in rail-fastening used on the National Railways of Mexico.

that these steel ties do not hold line and surface quite as well as wood ties. They are laid 11 to 13 per 30-ft. rail. Ties recently laid have the improved rail-fastening shown in Fig. 30, and with this fastening are expected to give a life of 40 or 50 years. It is more difficult to obtain a good joint with these steel ties than with wood ties but the total cost of maintenance is estimated to be about 25 per cent. less than with wood ties. It has been found that in stone ballast the tie is held better by finely crushed stone.

Though this section has proved very satisfactory on the National Railways of Mexico, traffic conditions here are so much more severe that the section would undoubtedly prove of little value on American railways.

71. Life of Steel Ties.—Steel ties have not been used on American roads long enough to determine their life. The life of the many types now on the market would undoubtedly vary considerably. Climatic, drainage and track conditions affect the life of steel ties more or less the same as wood ties. A test made by the Pennsylvania Railroad on screw-spikes (Art. 145) developed the fact that the brine drippings from refrigerator cars very greatly increased their corrosion and reduced their life. If steel ties were used under a similar condition the brine would undoubtedly have an injurious effect upon the tie. In 1908 the Bessemer & Lake Erie R. R. removed 10 inverted trough section Carnegie ties which weighed 199 lb. when placed in track in 1900. During 8 years service the average loss in weight due to corrosion was 20 lb. per tie or 2.5 lb. per tie per year. Two M-21 Carnegie steel ties installed in 1907 on the Pittsburgh, Shawmut and Northern R. R., and originally weighing 177 lb. each, were taken up and weighed in 1914. The average loss was 29.5 lb. in 7 years, or a loss at the rate of 4.2 lb. per year. In 1914, 30 M-21 Carnegie ties installed in 1908 on the Bessemer & Lake Erie R. R., and originally weighing 174 lb. each, were taken up and weighed. The loss averaged 1.6 lb. per tie per year. For these three cases the loss in weight per year, expressed in percentage of the original weight, was 1.3, 2.4, and 0.9 per cent., respectively. The average is about 1.5 per cent. If the tie is assumed to be so designed that failure will result only from corrosion, the life will be limited by the allowable reduction in weight. If a reduction of 30 per cent. reduced the strength of the tie so that failure resulted from breaking, the life would be 20 years. If a reduction of 20 per cent. produced the same result the life would be 13.3 years, which is less than the average life of all treated ties in Canada, the United States, and Mexico (Art. 64).

The following are the best available records of the length of time steel ties have been in service on American roads:[1]

(*a*) Carnegie steel ties of the M-21 section installed in 1904 by the Bessemer & Lake Erie R. R. were sound and in service in 1914. (*b*) Fifteen hundred M-21

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[1] From Vol. 16, Proceedings, American Railway Engineering Association.

Carnegie ties installed in 1905 by the Buffalo, Rochester & Pittsburgh Ry. were sound and in service in 1914. (*c*) Two thousand M-21 Carnegie ties installed in 1905 by the Duluth & Iron Range R. R. were still in service in 1914. (*d*) Of 3000 Carnegie ties with bolt and clip fastenings installed in 1907 by the Pittsburgh & Lake Erie R. R., 2000 were removed in 1914 and sold for scrap. (*e*) In 1914, Carnegie ties installed in 1907 by the Pittsburgh, Shawmut & Northern R. R. showed signs of buckling under the rail and the top angle appeared to be breaking down. (*f*) Twelve Rohm ties installed in 1910 by the Pennsylvania Lines, Northwest System, were in good condition in 1914 but the wedge rail-fastening was causing trouble.

In Switzerland steel ties in tunnels have rusted out in 8 to 10 years. On the North Western Ry. in India steel ties in track lost 41 per cent. of their original weight in 4 years. Steel ties on other Indian Railways were still in track after 16 years service. On the Netherlands State Railways, about 70 per cent. of the ties of the Post type were in track after 13½ years service. Steel ties weighing 177½ and 198 lb., and used experimentally on the London and North Western Railway, lasted only 12 years in main track.

72. Composite Ties.—The general type of composite tie is a steel shell filled with cement or asphaltic concrete. Composite ties, a small number of each of which have been placed in track by various railways, are the Atwood, Buhrer, Champion or National, International, Israel, Jennings, Mechlin and Smith, Reigler, Simplex, and Snyder. All are in the experimental stage. From length of service and point of numbers the most important composite tie is the Snyder. Over 5000 of these are in service, 150 on the Cornwall & Lebanon R. R., 2600 in the yard of the Midvale Steel Co., and 2566 in track on the Pennsylvania R. R. All have been in service since 1907 and were in good condition in 1914. The details of the tie are shown in Fig. 31. The tie consists of a steel casing 5/16 in. thick. The tie is 7 in. wide, 6 in. deep, and has an open bottom. The casing is filled by hydraulic pressure with a mixture of asphalt and crushed stone. The filling is held in place by inner bottom flanges on the sides of the casing. The edges of the tie are rounded to facilitate tamping. Each tie weighs 600 to 700 lb. All have been used under slow traffic.

The Champion or National steel tie is shown in Fig. 32. It consists of a ¼-in. steel shell open at the bottom, and flaring from a width of 7 in. at the top to 9 in. at the bottom. The height is 7 in. Several steel straps across the bottom prevent the sides of the shell from spreading. The shell is filled with concrete and the complete tie weighs about 600 lb. At the rail the top of the shell is reinforced by a steel plate 17 in. long, bolted to the under side. The plate is held in place by one bolt at each end. The nuts of the bolts are imbedded in the concrete. The heads of the two bolts act as guides for a tie-plate having a projection on each of its four corners. These projections hold the rail-clip square with the tie at all times—an important feature. The bolts holding the rail-clips pass through the top plate, steel shell and bottom plate. The tie-plate used on intermediate ties is 7 in. wide and 10½ in. long. For joint-ties the length of the plate is increased to 13 in. The tie may be insulated by placing sheets of fiber between the top and bottom plates and the shell of the tie, and by using bushings and washers of the same material on the bolts. In December, 1913, 203 of these ties were installed in main track by the Pennsylvania R. R.

The Atwood steel tie, designed by Mr. J. A. Atwood, Chief Engineer, Pittsburgh and Lake Erie R. R., consists of two ⅜-in. steel shells, each 3 ft. 6 in. long, open at the bottom and filled with concrete. The sides of the shell are prevented from spreading by three ¾-in. rivets spaced 15 in. apart. The middle section of the tie is not incased in the steel shell. Eight reinforcing rods, four at the top and four at the bottom, give strength to the middle section. The rail is held by square-headed bolts which bear directly against the rail-base.

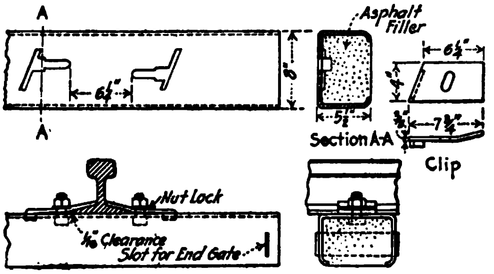


FIG. 31.—Snyder steel tie (composite tie).

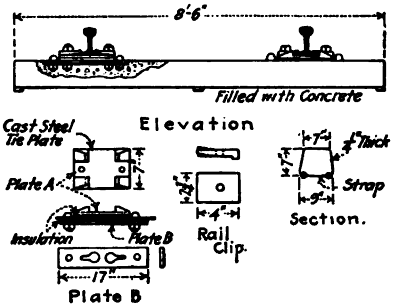


FIG. 32.—Champion or National steel tie (composite tie).

The Simplex steel tie consists of a steel shell open at the bottom, having a spool-shaped section, the top being flat. The shell is filled with concrete and the tie weighs about 370 lb. The rail-fastening consists of a bolt and clip. The head of the bolt is locked by a metal casting set in the concrete on the under side of the top shell. The tie can be insulated.

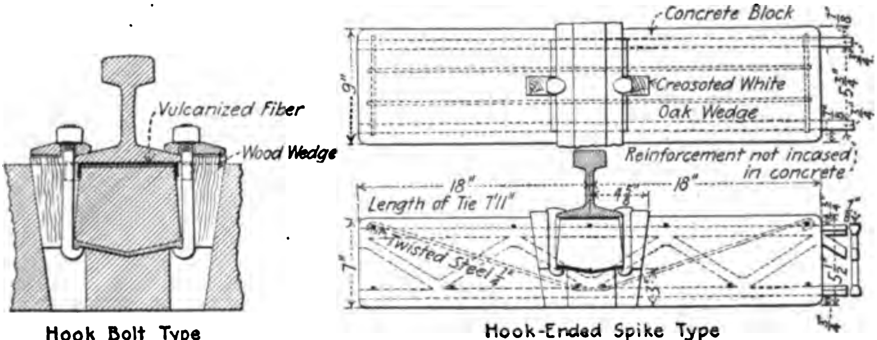
The Jennings steel tie consists of a steel shell with a wooden filler under each rail. No filler is placed in the middle section of the tie. Five of these ties were installed by the Baltimore and Ohio R. R. in 1906. These were removed in 1908, as the railway officials considered them unsuitable for main track. On Feb. 4, 1913, an attempt was made to have this tie tested at government expense, by the introduction of a resolution before the House of Representatives, providing for an appropriation of $25,000 and directing the Interstate Commerce Commission to investigate and report on the use of the Jennings Combination Railroad Tie. The resolution is still with the Committee on Interstate and Foreign Commerce.

73. Concrete Ties.—Because of the varied and extensive application of concrete during the past few years it is only natural that it would be tried as a substitute for the wooden tie. Several radically different designs of concrete ties have been patented. Those which have been experimented with to a very limited extent are the Affleck, Alfred, Bates, Brukner, Chenoweth, Corell, Hickey, Keifer, Kimball, and Percival. Some have already proved failures while others give promise of good results. Most of these ties are quite heavy and are hard to handle, but once they are in track their weight assists in holding line. They must be handled very carefully to prevent chipping and cracking the concrete. If the rail rests directly on the tie, the vibration and sawing action of the rail rapidly disintegrates the concrete under the rail-seat. Wood or metal tie-plates or cushions usually are placed under the rail to protect the concrete. A tie under load acts as a beam supported in the middle and loaded at both ends, producing tension in the top of the beam at its middle. As concrete cannot take tension reinforcement must be provided in the upper part of the tie to take up the tension. Where track circuits are used the position of the reinforcement in the tie may require the rail-fastenings to be insulated, as in some designs it is found that current enters the tie through the bolts by which the rail is fastened and enough current is picked up by the reinforcement and carried across to the other rail to cause a very heavy leakage of current. Concrete ties are damaged to a greater extent by derailment than steel or wood ties and have very little scrap value.

The Percival concrete tie consists of a block of concrete having a triangular section at the middle and flaring at the ends to almost a rectangular section. The tie is made both with and without a metal tie-plate which extends across the top to within about 11 in. of the ends. The rail rests on a wooden tie-plate about 2 in. thick. Four sockets of Babbitt metal are imbedded in the concrete and the rail is held to the tie by screw-spikes passing through the wood and steel plates and into the sockets. The tie is reinforced with ½- or ¾-in. rods placed in the corners. In 1906 the Florida East Coast Railway installed 16 of these ties at St. Augustine, Florida. In 1914 they were reported as still giving good service. In 1906 two lots of 50 of these ties were installed by the Galveston, Harrisburg and San Antonio Railway. Up to July, 1914, 33 ties of one lot had been removed or renewed. The ultimate failure of 17 of these resulted from a wreck. None of the other lot had been renewed in 1914. Fifty more ties were installed in 1910 and increased to 96 in 1914. No failure has occurred up to July, 1914.

The details of the Bates concrete tie are shown in Fig. 33. The reinforcement consists of two parallel trusses made by expanding rolled steel. These trusses are tied together by cross rods and the ends are incased in concrete blocks 9 in. wide and 7½ in. deep, extending 3 ft. from each end. The middle 23 in. of the reinforcement is not incased in concrete. The rail is secured by a hook spike or a hook bolt held by a wooden wedge driven in a cavity cast in the tie. The hook engages a plate embedded in the concrete. The rail rests on metal plates. Each tie weighs about 450 lb.

The design of the Kimball concrete tie is somewhat similar to that of the Bates tie illustrated in Fig. 33. It consists of two concrete blocks 3 ft. long, 9 in. wide, and 7 in. deep, with curved sides similar to a pole-tie. The two blocks are connected by two 3-in. by 1¼-in. by 8-ft. channels placed back to back, 2 in. apart, and bolted together. Wooden plugs are embedded vertically in the concrete. The rails rest on hardwood blocks 3 in. thick and are held by spikes driven through these blocks and into the wood plugs. One of these ties installed in 1902 by the Pere Marquette Railroad was taken out in 1911 and installed in a low-speed track of the Pennsylvania Lines, S. W. In 1914 it was still in track but was commencing to crack.



Hook Bolt Type of Rail Fastening.

Hook-Ended Spike Type of Rail Fastening.

Fig. 33.—Bates concrete tie.

ECONOMICS OF TIES

74. Total Capitalization.—Several things must be considered in determining which of several kinds of ties will prove the most economical. These are (1) the first cost of the tie; (2) the life of the tie; (3) the labor and material cost of renewals; (4) the rate of interest which must be paid on money; (5) the annual cost of maintenance; (6) the value of material released or the scrap value of the tie after it is removed from main track. The cost of maintenance is almost the same for all kinds of wooden ties, and the value of material released is so little that items 5 and 6 need not be considered in determining the relative value.

On a basis of capitalization, the cheapest tie will be the one for which the first cost of labor and material of the tie installed in track, plus an amount set aside at compound interest as a sinking-fund which will produce the tie forever, is a minimum.

The formula for computing compound interest is $a = p(1 + R)^n$, where n = time in years, R = rate of interest expressed decimally, p = the number of dollars originally invested or the principal, and a = total amount or principal plus accrued interest at the end of "n" years. Applying this formula to the tie problem and letting n = life of tie in years, at the expiration of the life of the tie the amount necessary to replace it would be $a = p(1 + R)^n$. This amount would be sufficient only to buy and install a new tie and there would be no principal left. Therefore, the initial amount set aside must be sufficiently large so that the interest alone at the end of "n" years will produce the tie, leaving the principal still at interest. In this way the interest alone will replace the tie at intervals of "n" years and the life of the tie is made perpetual.

Then, at the end of "n" years the amount available will be $p(1 + R)^n - p$. This amount must equal the labor and material cost of renewing the tie, or it may be called the first cost of the tie, and of course does not take into consideration any future increase in the cost of ties.

Let C = first cost of tie installed in track.

Then,
$$C = p(1 + R)^n - p,$$
$$= p[(1 + R)^n - 1], \qquad (74a)$$

and,
$$p = \frac{C}{(1 + R)^n - 1}, \qquad (74b)$$

which gives the required principal or amount that must be first set aside in order to make the life of tie perpetual. This is in addition to the first cost of the first tie. Therefore, the total initial outlay of capital is,

$$C + p = C + \frac{C}{(1 + R)^n - 1},$$
$$= \frac{C(1 + R)^n}{(1 + R)^n - 1}. \qquad (74c)$$

In case tie-plates are used on the tie, the life of the tie-plates will be different from the life of the tie and the total capitalization will be found as follows: Let T = first cost of two tie-plates installed, p_t = sum to be set aside which at compound interest for n_t years will produce a sum T, and n_t = life of tie-plate in years. The total capitalization will be the first cost of tie, plus the first cost of two tie-plates, plus the sum to be set aside to perpetuate the tie, plus the sum to be set aside to perpetuate the tie-plates, or total capitalization $= C + T + p + p_t$. (74d)

Similarly to 74*a*,

$$T = p_t[(1 + R)^{n_t} - 1],$$

$$p_t = \frac{T}{(1 + R)^{n_t} - 1}.$$

Substituting in 74*d*,

$$\text{Total capitalization} = C + T + \frac{C}{(1 + R)^n - 1} + \frac{T}{(1 + R)^{n_t} - 1},$$

$$= \frac{(C+T)(1 + R)^n - T}{(1 + R)^n - 1} + \frac{T}{(1 + R)^{n_t} - 1}. \qquad (74c)$$

The cost of steel ties is based on the weight but is increased by complicated sections and fastenings. In considering the cost of a substitute tie more things must be taken into consideration than for a wood tie.

The cost of installing, maintaining, and removing substitute ties differs greatly for different designs. For a given case these should be considered along with the first cost of the tie. There is also a certain scrap value for old steel ties, being about 0.5 ct. per pound for about 60 per cent. of the original weight. The total capitalization for a tie having a scrap value is found as follows: Let V = scrap value of the tie. Therefore, the actual amount of money required to completely renew the tie will be $C - V$. Then,

$$C - V = p(1 + R)^n - p,$$

$$p = \frac{C - V}{(1 + R)^n - 1}. \qquad (74f)$$

$$\text{Total capitalization} = C + p = \frac{C(1 + R)^n - V}{(1 + R)^n - 1} \qquad (74g)$$

75. Annual Cost.—The cost of the tie may also be considered from the standpoint of annual cost. In this case the life of tie is not made perpetual by setting aside a permanent principal, but renewal is provided for by setting aside an equal sum each year which at compound interest will provide a fund, including principal and interest, sufficient to renew the tie at the expiration of its life. On this basis, the cheapest tie is the one having the cheapest annual cost, that is, the one in which the annual interest on first cost plus the amount that must be set aside each year, is a minimum.

A sinking-fund is usually created by an annuity, that is, a succession of equal installments paid annually, and the compound interest earnings of these installments.

Let S = amount of the sinking-fund.
n = the time in years for its creation (life of tie in years).
I = the annual installment paid at the end of each year of the period "n."

Then S must equal the first cost of the tie, or,

$$\begin{aligned} S &= C, \\ &= p[(1+R)^n - 1], \text{ from Eq. } 74a. \end{aligned}$$

But,

$$p = \frac{I}{R},$$

then,

$$\begin{aligned} S &= \frac{I[(1+R)^n - 1]}{R}, \\ I &= \frac{SR}{(1+R)^n - 1}, \\ &= \frac{CR}{(1+R)^n - 1}. \qquad (75a) \end{aligned}$$

Let $A = CR$ = annual interest on first cost of tie. The total annual cost will be

$$\begin{aligned} I + A &= \frac{CR}{(1+R)^n - 1} + CR, \\ &= \frac{CR(1+R)^n}{(1+R)^n - 1}. \qquad (75b) \end{aligned}$$

The annual cost of a tie with tie-plates will be the interest on first cost of tie, plus the interest on first cost of two tie-plates, plus annual installment to be placed at compound interest to provide for renewing the tie at expiration of its life, plus annual installment to be placed at compound interest to provide for renewing the tie-plates at expiration of their life.

Let S_t = amount of sinking-fund for two tie-plates.
I_t = the annual installment to the tie-plate sinking-fund paid at the end of each year of the period n_t.
A_t = the annual interest on first cost of two tie-plates.

Then, total annual cost $= I + A + I_t + A_t$, (75c)

and S_t must equal first cost of tie-plates, or

$$\begin{aligned} S_t &= T. \\ I_t &= \frac{TR}{(1+R)^{n_t} - 1}. \\ A_t &= TR. \end{aligned}$$

$$\begin{aligned} \text{Total annual cost} &= \frac{CR}{(1+R)^n - 1} + CR + \frac{TR}{(1+R)^{n_t} - 1} + TR, \\ &= \frac{R[(C+T)(1+R)^n - T]}{(1+R)^n - 1} + \frac{TR}{(1+R)^{n_t} - 1}. \qquad (75d) \end{aligned}$$

For steel or other ties having a scrap value,

$$I = \frac{(C-V)R}{(1+R)^n - 1}, \text{ similarly to Eq. } 75a.$$

$$I + A = \frac{CR(1+R)^n - VR}{(1+R)^n - 1}. \qquad (75e)$$

76. Equivalent Cost.—On a basis of equivalent cost two ties would be considered to cost the same if the total capitalization of one equaled that of the other or if the annual cost of one equaled that of the other. Considering total capital, let C = first cost of tie as considered before, C_1 = first cost of another kind of tie, p = as before, p_1 = principal for tie costing C_1, and n_1 = the life of this tie.

Then the two ties are considered to cost the same when

$$C_1 + p_1 = C + p.$$

From Eq. 74*c*,

$$\frac{C_1(1 + R)^{n_1}}{(1 + R)^{n_1} - 1} = \frac{C(1 + R)^n}{(1 + R)^n - 1},$$

$$C_1 = \frac{C(1 + R)^n[(1 + R)^{n_1} - 1]}{[(1 + R)^n - 1](1 + R)^{n_1}}. \qquad (76a)$$

Considering annual cost and letting I_1 and A_1 equal annual installment and annual interest respectively, on first cost of second tie, then the two ties are considered to cost the same when

$$I_1 + A_1 = I + A.$$

From Eq. 75*b*,

$$\frac{C_1R(1 + R)^{n_1}}{(1 + R)^{n_1} - 1} = \frac{CR(1 + R)^n}{(1 + R)^n - 1},$$

$$C_1 = \frac{C(1 + R)^n[(1 + R)^{n_1} - 1]}{[(1 + R)^n - 1](1 + R)^{n_1}}, \qquad (76b)$$

which is the same as Eq. 76*a*.

A similar solution can be applied to the case where tie-plates are used or where there is a final scrap value. The method given for ties having a scrap value could also be used for ties having tie-plates.

77. Examples.—1. To illustrate the use of these formulas, suppose it is desired to determine whether a pine tie costing 60 cts. in the track is cheaper than a white-oak tie costing 70 cts. in the track, if the life of the pine tie is 6 years and that of the oak tie 9 years. Assume interest to be 4 per cent. From Eq. 74*c* the total capitalization would be $2.82 for the pine tie and $2.37 for the white-oak tie, showing that the latter would be the cheaper tie to use on a basis of total capitalization.

2. To investigate the relative economy of the two ties on a basis of annual cost substitute in Eq. 75*b* and it will be found that the annual cost of the pine tie is 11.3 cts., and that of the oak tie 9.5 cts.

3. Assuming the cost and life of both as at first, by substituting in Eq. 76*b* it is found that the equivalent cost of the two ties would be the same if the pine tie cost 50.3 cts. That is, for a white-oak tie costing 70 cts. and lasting 9 years and a pine tie costing 50.3 cts. and lasting 6 years, the total capitalization and the annual cost would be the same for each tie.

4. Assuming that the first cost and life are the same as given before but that two tie-plates costing 15 cts. each and having a life of 20 years are used on the pine tie, the total capitalization for the oak tie is $2.29 as computed before. Substituting in Eq. 74*e*, the total capitalization for the tie-plated pine tie would be $3.74. The annual cost of the oak tie would be 9.1 cts. as before, while from Eq. 75*c* the annual cost of the pine tie with tie-plates is found to be 15 cts.

5. Assuming the life and cost of a white-oak tie as before, the annual cost is 9.5 cts. For a steel tie costing $4.00 in the track, having a life of 20 years and a scrap value of 0.5 ct. per pound for 60 per cent. of an initial weight of 270 lb., from Eq. 75*e*, the annual cost would be 26.7 cts.

6. Assume a red-oak tie to cost 40 cts. and last 4 years untreated. What would be the justifiable expenditure for a preservative treatment that would increase the life to 8 years? From Eq. 76*a*, the equivalent cost of a tie lasting 8 years is found to be 72.9 cts. Hence it would be justifiable to spend 32.9 cts. on the treatment, and if the cost of the treatment was less than this an actual saving would result.

CHAPTER VII

THE PRESERVATION OF TIMBER

78. Agencies of Decay in Timber.—The rusting of iron or the disintegration of stone is an inorganic process, but the decay of wood is organic and results from the activities of low forms of plant life called bacteria and fungi. Bacteria are one of the simplest forms of life and often consist of but a single microscopic cell. The cells usually are colorless and multiply by the division of one cell into others which in turn divide, so that once started they multiply very rapidly.

Fungi are more complicated than bacteria. The spores or seeds of the fungi are fine like dust and are carried about by the wind. Heat, air, and moisture are necessary for the germination of the spores, and after germination, food, in addition to the other three elements, is necessary for the development and growth of the fungi. If a spore lodges in dead timber and there is proper heat and moisture, it germinates and sends out a thin white thread which branches out in all directions and eventually penetrates all parts of the wood. But few species of fungi are parasites and can successfully attack healthy living trees. These must die when the wood is cut and hence are not a cause of decay in cut timber.

Wood-structure is composed of very small cells. The fundamental material of all plant-structure is cellulose. This is a white insoluble substance. Bleached cotton is almost pure cellulose. The harder substance of the wood is called lignin. Most fungi attack only the lignin; others attack only the cellulose, while some few attack all parts of the wood. These substances are dissolved by secretions from the fungus and thus serve as food for its growth. After this process has continued for some time a large part of the wood-fiber has been dissolved by the fungus, the strength of the wood is much reduced, the texture is porous, and the wood is "rotten."

79. Prevention or Retardation of Decay.—Since heat, air, moisture, and food are necessary for the development of fungi, if one or more of these necessities can be kept from the fungus it must die. In most practical cases heat and air are beyond control. By proper care the percentage of moisture in the wood can be very greatly reduced. All green or freshly cut timber contains a large percentage of moisture. By piling the timber in such a way as to permit free access of air (see Fig. 24), the moisture may be reduced to about 15 per cent., the actual amount depending on the climate. The amount of moisture can be reduced still further by kiln-drying the timber. By proper seasoning in this way the development of fungi is very much retarded. Seasoned timber has the power to reabsorb moisture when put in damp locations so that the benefit of seasoning may not be permanent in reducing the action of decay.

By coating the exterior of dry timber, either by dipping or painting, with a thin layer of some waterproofing material, the development of fungi may be further retarded because moisture will be kept out of the timber and fungi will be prevented from entering the wood as long as it does not split or check. The best and only permanent method of preventing the development of fungi is to deprive them of food. This can be done by injecting poisonous substances into the wood so that the organic matter of the wood is changed from a food for fungi into a fungicide.

80. Early History of Wood Preserving.—Many centuries ago the ancients were in the habit of painting their statues with oily preparations to preserve them from decay. The great wooden statue of Diana at Ephesus was painted with oil of nard for this purpose.

The treatment of wood with preservatives was in general use in Europe before it was in America. The later developments, however, have occurred almost simultaneously on the two continents. Active progress in wood preserving really commenced with the invention of the locomotive and the necessity, which was at once apparent, for protecting the ties from decay. The industry increased rapidly and soon more wood was being treated for use as ties than for all other purposes, and at the present time about 90 per cent. of all wood treated in the United States consists of railway-ties.

The earliest record of the use of treated ties is on the Central Railroad of Maryland in 1838, when some chestnut ties treated with chloride of mercury (Kyan's process) were laid. In 1840 some oak ties treated by the same process were laid on the Chesapeake and Ohio. These ties were reported to have lasted 12 to 15 years.

The first wood-preserving plant of any size built in America was that at Lowell, Mass., built in 1848 by the proprietors of the locks and canals at that place, and was intended to treat wood for use in canal work and not for railways. The plant consisted of two wooden tanks or vats, each 50 ft. long, 8 ft. wide and 4 ft. deep, containing a solution of chloride of mercury in which the timber was immersed. This plant was still in operation in 1915. For several years after the erection of this plant little progress was made in the treating industry in the United States. The Philadelphia, Washington and Baltimore Railroad and the Philadelphia and Reading Railroad each built treating plants, the former in 1863 and the latter in 1867, and commenced treating their ties with zinc chloride. The result was not satisfactory as the ties were found to be very brittle after treatment, though slow to decay. This brittleness was doubtless the result of using a solution which was too strong.

In 1875–1876 the Louisville and Nashville Railroad built a treating plant at Pascagoula, La., using creosote oil under pressure. The plant was built primarily to treat timber used in trestle- and dock-construction. The first use of creosoted piles was more for the purpose of protecting them from the attack of sea-worms than to prevent decay. This use has expanded until at present large quantities of creosoted piles and structural timber are used in all parts of the country, even though not subject to the attack of sea-worms. In 1877 and 1878, 600 long-leaf yellow pine ties treated at the Pascagoula plant were placed in the track and were not removed until 1905, 27 years later.

In 1876 the Houston and Texas Central Railroad built a plant at Houston, Texas, to treat all kinds of timber with creosote oil. During the next 8 or 10 years several other railways made tests with treated cross-ties. In general, the results were so successful that in 1885 the Atchison, Topeka and Santa Fe Railway built a plant at Las Vegas, N. M. This was the first treating plant built exclusively for the treating of cross-ties and was operated continuously until 1906 when it was abandoned. Because of the construction and long operation of this plant the Santa Fe may be considered as the pioneer company in treating and using its own cross-ties. In the early operation of the plant the preservative used was zinc chloride and tannin but during the last years of its operation zinc chloride was used alone. In 1897 two additional plants were built by the Santa Fe, one at Somerville, Texas, operated by the Texas Tie and Lumber Company, and the other at Bellemont, Ariz. In 1891 the Southern Pacific R. R. built a plant at Houston, Texas, and in 1894 built a portable plant in Oregon. The Burnettizing method was used at both plants.

Real progress in the preservation of timber commenced about 1900 and since then the growth of the industry has been very rapid. In 1903 there were 27 timber-treating plants in the United States and in 1913 there were 93, 26 of which were operated by steam-roads. The greatest number of new plants erected during any one year was in 1907 when 12 were built.

81. Growth of the Industry.—In Canada practically no treated ties were used until after 1910, but since that year there has been a rapid increase in their use and in 1913 about 10 per cent. of all cross-ties purchased were treated with some preservative. In 1915 there were five treating plants in Canada, four using creosote and one using zinc chloride.

In Europe more metal ties are used by the railways than is the case in America and the ties are spaced farther apart so that the number of wooden ties per mile of track is less. About 85 per cent. of all wooden ties are treated. There are between 65 and 70 timber-treating plants and the total number of treated ties used per year was about 16,600,000 prior to 1914.

Prior to January 1, 1900, some 15,000,000 ties had been treated in the United States, about 96 per cent. of which were treated with zinc chloride and 4 per cent. with creosote oil. In 1903, 9,010,000 ties were treated, of which 93.3 per cent. were with zinc chloride and 6.7 per cent. with creosote oil. In 1905, 14,890,000 ties were treated, of which 90 per cent. were with zinc chloride and 10 per cent. with creosote oil. In 1913 over 69 per cent. of all timber treated was with creosote and 23 per cent. with zinc chloride. The actual amounts of preservatives used in that year were 108,373,000 gal. of creosote, 26,466,000 lb. of dry zinc chloride and 3,886,000 gal. of other preservatives. The proportion of treated ties to the entire number used has increased from 1 per cent. in 1886 to 24 per cent. in 1912 and 30 per cent. in 1913. The greatest progress in the use of treated ties has been made on western roads.

82. General Considerations.—The use of treated ties instead of untreated ties is purely an economic consideration depending on the relation between the cost of treated and untreated ties, tie-renewals and track work under the conditions of location and traffic of any particular railway. The principle is the same for timber used for other purposes.

As will be seen from the detailed descriptions of the various methods of treatment now employed, the principle of the treatment in most processes is first to extract the moisture and then replace it under pressure with a material which fills the cells of the wood and prevents decay. The best results with most woods are obtained if the timber is thoroughly air-seasoned before applying the treatment, and after treating, if treated with a water solution, by allowing the ties to stand several weeks before being used, in order to let the wood thoroughly dry out and thus precipitate the chemicals. Some timber-treating experts are of the opinion that certain close-grained timbers, especially Oregon red fir, give better results if treated green. Also, in some very inferior woods, in hot, moist climates decay commences before seasoning is complete, so that to prevent any decay the timber must be treated very soon after it is cut.

Experience in the past has shown that woods of different species and even woods of the same species are not equally benefited by a similar treatment. After considerable investigation, the American Railway Engineering Association recommends that timber to be treated should be grouped before treatment as follows:

1. Ties of approximately the same period of seasoning should be grouped together for treatment; green ties should never be mixed with seasoned ones.

2. Pine ties should be separated on the basis of heart-wood and sap-wood; it would also be advisable in some cases to group hardwoods on the same basis but it is not generally practical to do so.

3. Grouping on the basis of species and families, as for example red oak, pines, beeches, etc., if a further division into heart-wood classes is

made with pine, is usually a satisfactory practice. From this it follows that red oak, beech, long-leaf pine, loblolly-pine, and gum should be treated separately. Birch and hard maple and certain other combinations, depending on the locality, can be grouped together to advantage.

4. The separation in the seasoning-yard, on the basis on which the ties are to be grouped for treatment, is an essential and economical practice.

Figure 34 shows the way in which ties are piled in the seasoning-yard.

While zinc chloride was at one time the most commonly used of all preservatives, creosote oil has now largely taken its place. Though creosote is much more expensive than zinc chloride it is much more effective, and now it is being used in improved processes and in combination with other chemicals with a view to reduce the cost of the treatment.

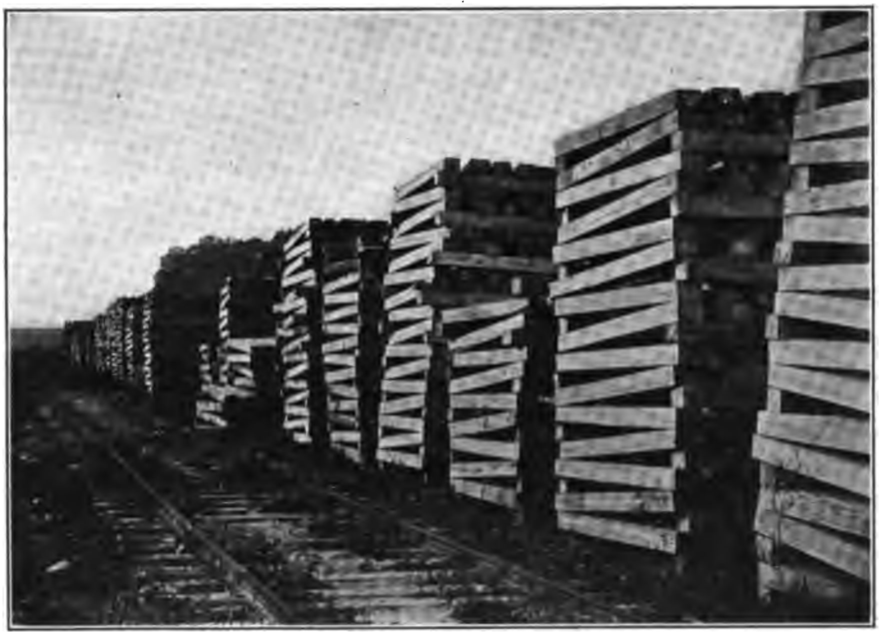


FIG. 34.—Ties in seasoning-yard at timber-treating plant.

The preservative value of a chemical depends upon several properties both chemical and physical, as follows:

1. It may contain a poisonous or antiseptic component.
2. It may be capable of adhering to the fiber and cell walls of the wood with such tenacity as to prevent conditions favorable for the development or existence of organic elements destructive to the timber.
3. It may contain a viscous material which will deposit a film on the external surface of the timber, and thus prevent any destructive elements

from entering the wood as long as the water-proof surface remains unbroken.

The prevention of decay may be permanent or temporary, depending on the kind and quality of the antiseptic used. If the timber immediately after treatment and before use shows the full treatment specified, but after being used for some time shows a less quantity of the chemical, due to its volatilization or its having been leached out by moisture and rain, the treatment was deficient and ultimate failure will result.

A combination of the first two of the above processes gives an ideal means of preservation. In such a treatment all organisms in the timber are killed at the time of treating and outside organisms are later prevented from entering the timber. Such a combination would be an antiseptic combined with some stable oil which will adhere to the fibers of the wood. With our present knowledge of timber preservation the occasion for replacing treated timber because of decay should never occur; and when it does occur it is because the proper antiseptic was not used or the treatment was not properly applied.

If the treating solution is composed of a mixture of several materials differing considerably in the mobility of their particles the penetration of the more fluid materials will be decreased by the resistance offered by the more viscous ones. Within certain limits, the amount of penetration also depends on the temperature of the liquid, because as the temperature increases the viscosity decreases and the liquid will more readily enter the pores of the wood. The amount of penetration is also affected by the size and arrangement of the wood-cells. This accounts for the fact that timbers of the same species take treatment to various degrees.

83. Preservatives.—Four preservatives are now in use in America. These are, in order of importance, (1) creosote, (2) zinc chloride, (3) a combination of creosote and zinc chloride, (4) mercuric chloride. The second and fourth of these are each applied in but one way. The first and third are applied in several distinctive ways.

In addition to the above the Powel process is used by one timber-treating company in England. The chemical used is saccharine. The timber, generally green, is boiled in a solution of sugar and water, either in an open tank or a closed cylinder, after which it is kiln-dried and is then ready for use. It has been proved without doubt that sugar will not preserve wood, hence the success of this treatment is very doubtful.

Other methods that have been used more or less extensively in the past but which have been abandoned for one or more of several reasons are as follows:

1. *Vulcanizing,* which consisted of subjecting the timber to an air-pressure of 100 to 175 lb. at a temperature of about 500°F. At one time

it was used to some extent by the elevated railways of several cities. The treatment was quite expensive and the results were not permanent as the treatment simply sterilized and dried the timber.

2. *Creo-resinate process.*—The timber was first steamed and a pressure of 80 lb. per square inch was applied. A vacuum was next drawn and was held for a short time and then was suddenly released, at which time a solution of creosote, melted resin, and formaldehyde was let into the cylinder. The timber was then placed in a second cylinder and treated with a solution of milk of lime. The treatment gave good results but was commercially impracticable. It was later modified to a use of resin and formaldehyde and was finally abandoned.

3. *Thilmany process,* in which the timber was first treated with a solution of sulphate of copper or zinc and then with a solution of barium chloride.

4. *Margaryizing or Boucherizing,* using sulphate of copper. The names were originally given to the treating process in which the solution was applied under hydrostatic pressure to the end of the timber to be treated, so that the solution would be forced through the pores of the wood. As the chemical generally used was sulphate of copper, by custom the names now refer to the use of that chemical rather than to the method of application. This salt attacks iron; hence the treatment is objectionable from a structural standpoint.

5. *Hasselman process,* in which the timber was boiled in a solution of copper, iron and aluminum to which a small amount of kainite had been added. Kainite is a salt consisting of potassium-magnesium chlorosulphate. Instead of preserving the timber the chemicals had a disintegrating action upon it.

6. *Hagan process,* which made use of a solution of zinc chloride to which was added a solution of gypsum.

7. *Wellhouse process.*—This is now out of use but the result from ties, especially of a porous nature, treated by this process has been so good that the treatment may yet be revived. It is undoubtedly the most important of all processes in this list of those that have gone out of use. Ties treated by it have given 4 years longer life than similar ties treated with zinc chloride. Zinc chloride, being soluble, will be leached out of timber placed in damp locations. In this process the zinc chloride treatment is administered as described in Art. 90, a 0.5 per cent. solution of glue having first been added to the zinc chloride solution. The cylinder is then emptied and recharged with a solution of tannin. The tannin penetrates only a short distance into the wood, but combines with the glue and forms a leathery water-proof substance which closes the outer cells of the wood, preventing the entrance of moisture and holding the zinc chloride in the tie. Ties treated by this process and used on the Chicago, Rock Island and Pacific Ry. gave an average life of 11.2 years.

84. Creosote.—Creosote oil is obtained as a by-product from the distillation of coal-tar in the manufacture of paving-pitch, roofing-pitch, core-pitch, etc. In the process of distillation the first distillates to pass over are the ammoniacal liquor and benzol. The distillates following these are taken as a whole and constitute what is known as creosote oil. If the material being made is a hard pitch, such as core-pitch, the distillation of the tar is carried to a much higher degree than in producing the softer pitches. The production of the hard pitches gives the greatest quantity of creosote oil, so that the percentage of volatile oils is much less.

In manufacturing a paving-pitch the volume of the distillate obtained is from 10 to 20 per cent. of that of the tar. This oil passes over at a low temperature and is all more or less volatile. Roofing-pitch is a harder pitch than that used for paving and the distillation is carried to a higher temperature, so that the volume of the oil obtained is from 25 to 30 per cent. of the tar. About the first half of the final volume is composed of the volatile oils while the last half that comes over is a good oil. In manufacturing the harder pitches, the volume of oil obtained is about 40 or 45 per cent. of the tar. The first quarter of this is the light volatile oil, the second quarter is good oil, while the last half is the best oil obtainable. Unless the oil is purchased under rigid specifications and the product tested to determine the quality, the manufacturers will sell a mixture of the first two or of all three as creosote oil. One of the principal preservative constituents of creosote oil is naphthalene. The tar acids such as phenol (carbolic acid) and cresol are also excellent preservatives but are volatile and soluble and soon completely disappear from the wood. In the process of manufacture carbolic acid, naphthalene, or some other chemical may be recovered as a by-product. In American manufacture a soft pitch is what has generally been desired, while in Europe much hard pitch has been manufactured. Accordingly, the best creosote oil in the past has come from Europe. Because of the different qualities of pitch manufactured and the different by-products recovered commercial creosote oil may vary greatly in quality.

The heavy creosote oils have a high boiling point and consequently are but slightly volatile, are almost insoluble in water, hence are not easily leached out by rain and moisture, and there is a strong chemical union of the components so that the chemical composition is not easily changed. Therefore, these heavy creosote oils make an ideal wood preservative.

The American Railway Engineering Association has adopted specifications covering three grades of creosote oil. The specifications for grade 1 oil are given below and represent the requirements for an ideal oil. As it is not always possible to get this quality, less rigid specifications were prepared for grades 2 and 3.

Specifications for Grade 1 Oil:

"The oil used snall be the best obtainable grade of coal-tar creosote; that is, it shall be a pure product obtained from coal-gas tar or coke-oven tar and shall be free from any tar, oil or residue obtained from petroleum or any other source, including coal-gas tar or coke-oven tar; it shall be completely liquid at 38°C. and shall be free from suspended matter; the specific gravity of the oil at 38°C. shall be at least 1.03 when distilled by the common method—that is, using an 8-oz. retort, asbestos covered, with standard thermometer, bulb ½ in. above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give no distillate below 200°C., not more than 5 per cent. below 210°C., not more than 25 per cent. below 235°C. and the residue above 355°C. if it exceeds 5 per cent. in quantity, shall be soft. The oil shall not contain more than 3 per cent. water."

Four processes of applying creosote are now in use in America; (1) the Lowry process, (2) the Rueping process, (3) the old or steaming process, and (4) the boiling process. The first two named belong to the so-called "empty cell" process. The origin of this name will be understood from the following descriptions of the two processes.

85. Lowry Process.—The seasoned timber is placed in the cylinder, the doors are closed and creosote at a temperature of 180°F. is admitted. A pressure ranging from 100 to 175 lb. per square inch is then applied and maintained until practically no more oil can be forced into the timber. The cylinder is quickly drained and a quick, high vacuum created, thus drawing a portion of the oil out of the wood, the specified amount being left in. (For ties the usual amount left in the wood is about 8 lb. per cubic foot.) After breaking the vacuum the cylinder is again drained and the charge withdrawn. With this method a deep penetration is obtained irrespective of the amount of creosote left in the timber. This process is used at some fifteen treating plants in the United States, two of which are operated by the Northern Pacific Railway, and at one plant in Canada.

86. Rueping Process.—The seasoned timber is placed in the cylinder, the doors are closed and the air-pressue in the cylinder is raised to from 75 to 100 lb. Creosote is then forced into the cylinder, using a slightly higher pressure than that of the compressed air. As soon as the cylinder is full of creosote the pressure is raised to from 200 to 250 lb. and held until the timber will absorb no more oil. The pressure is then released and the cylinder drained. The expanding of the compressed air in the cells of the wood forces out a portion of the oil, leaving in the specified amount. A vacuum of short duration is finally applied to assist in freeing the surface of the timber of oil. About six plants are now using this process.

87. Old or Steaming Process.—This process is divided into three parts, namely, steaming the timber, removing the moisture from it by vacuum, and impregnating it with creosote. After the timber charge is sealed in the cylinder steam is admitted and the temperature raised to about 250°F. This is maintained for from 6 to 16 hours. A vacuum of about 26 in. is then created and held for from 2 to 6 hours. Creosote is next admitted and held for 3 hr. at a pressure of about 150 lb. and at a temperature above the boiling point of water. The oil is then withdrawn, and after draining a few minutes the timber is withdrawn. The absorption is from 8 to 15 lb. per cubic foot. (The European practice is to use a heavier treatment, the absorption being from 12 to 30 lb. per cubic foot.) This process is now being used in America at some half dozen treating plants.

88. Boiling Process.—This treatment was designed particularly to treat unseasoned Douglas fir. There is less danger of weakening timber by boiling or "oil-seasoning" than by steaming. The treatment is applied as follows: The timber is placed in the cylinder and creosote oil at a temperature of 160°F. is pumped into the cylinder until all timber is covered, but the cylinder is not entirely filled. The temperature is then raised to 220°F. by passing steam through coils in the cylinder. The temperature is kept at this point until the condensation of the vapor coming from the wood, as collected in the condensing chamber, is not more than ⅛ lb. of water per cubic foot of timber per hour. The vent is then closed and creosote at a temperature of 180°F. is pumped into the cylinder and the pressure is raised to 125–150 lb. and so maintained until an absorption of 10 lb. per cubic foot of timber has taken place. A slightly lower temperature and pressure are used when dry seasoned timber is being treated.

89. Adulteration of Creosote Oil and Substitute Treatments.—Although the most effective, creosoting is also the most expensive treatment. Experiments made at the United States Forest Products Laboratory by the so-called "Petri dish" method show that 0.55 per cent. of creosote oil prevents the growth of the most hardy fungi. If these figures could be applied to treated wood only 0.343 lb. of creosote per cubic foot would be required, while the amount actually injected is twenty to fifty times this quantity. Similar experiments with zinc chloride indicate that 0.468 lb. per cubic foot is required, while the usual treatment is about ¼ lb. per cubic foot. These experiments would indicate that much more creosote is injected than is really required. Upon this is based the use of a mixture of creosote with some other substance, the object being to decrease the cost of the treatment without materially affecting its efficiency.

Since 1907 a mixture of creosote and coal-tar has been used extensively at several treating plants. Since that date almost all treated wood paving-blocks used in the United States have been treated with such a mixture and since 1908 about 24,500,000 ties have been treated with a mixture composed of 80 per cent. creosote and 20 per cent. tar. As creosote is made from tar, tar cannot be considered strictly as an adulterant when added to creosote. In some cases the tar has been added at the plant simply as an adulterant and without the knowledge and consent of the purchaser of the treated timber. In other cases the specifications allow the addition of coal-tar. The use of this mixture is by no means new, as in the first process patented by Mr. John Bethel in 1838 a mixture of 1/8 to 1/2 of coal-tar with creosote was specified. But since the preservative value of coal-tar is not yet definitely known it should be used only by consent of all parties concerned.

Crude oil having an asphalt base has been used to a limited extent in timber treating. One railway has used a large number of ties treated with it. These have been in service long enough to show that little or no benefit results from the treatment. The only benefit results from the oil acting as a waterproofing. If a less quantity of creosote than now considered standard will prove sufficiently antiseptic, crude oil might well be used in many cases as an adulterant for filling the cells of the wood.

The name creosote rightly belongs to the oil obtained from the destructive distillation of wood, but the term is now loosely applied to any oils resembling this which are obtained from any kind of tar. It appears that of the wood-tar creosotes, those produced from hardwoods are superior to those from softwoods in antiseptic properties and are even stronger in this respect than the average coal-tar creosote. Wood-tar creosote is high in tar acids but these are quite volatile and soon disappear from wood treated with this oil. As an equal grade of wood-tar creosote costs two or three times as much as coal-tar creosote there is no reason to expect an increase in its use for timber treating.

Water-gas-tar results from the manufacture of water-gas, which is obtained by passing steam over incandescent coke or anthracite coal and then through a spray of petroleum. By distilling this tar, a product called water-gas-tar creosote is obtained. It has been used to some extent both alone and mixed with coal-tar creosote. Arch Street, Philadelphia, was recently paved with wood blocks treated with this oil. In the past it has been 1 or 2 cts. per gallon cheaper than coal-tar creosote. On account of the present lack of definite data as to its efficiency and the uncertainty of its preservative value its use as a wood preservative is not recommended.

Sodium fluoride has been tried as a timber preservative recently in Europe with very promising results. The salt can be produced quite cheaply in America. Laboratory tests show that it is from two to five times as toxic as zinc chloride, has a less corrosive action on flange steel and is less soluble than zinc chloride, and is about as toxic as coal-tar creosote.

90. Zinc Chloride.—This is the best known preservative that is used as a substitute for creosote because of the high cost of the latter. The zinc chloride treatment, otherwise known as Burnettizing, until recently was used more than any other treatment. It is still used more than any other preservative except creosote. Its value as a preservative has been thoroughly tested during the past 80 years. Under most conditions of service it does not increase the life of the tie as much as creosote and with the prices which have prevailed up to the present the annual charge against a Burnettized tie has been greater than for a creosoted tie.

Zinc chloride is obtained by dissolving metallic zinc in hydrochloric acid. The presence of even very small quantities of free acid will make the timber brittle. The solution used in treating is diluted with water. Ties have been treated with solutions as strong as 4 per cent. without making them brittle. The best results are obtained by using a weak solution and a maximum amount of absorption. The material is soluble and may in time be leached out of the timber, so that the quantity used should depend on the kind of wood and service and climatic conditions. The following method of treatment is used by the Southern Pacific R. R. and is typical of this form of treatment:

The ties are placed in the cylinder which is then sealed. Steam is admitted at such a rate as to secure a pressure of 40 lb. in the cylinder within 2 hours. This pressure is maintained for from 3 to 6 hours. An open vent is provided in the bottom of the cylinder to permit the escape of air and water. The length of the steaming period may be determined by the presence of sap in the escaping water. When the water clears up and contains no more sap steaming may be stopped. The steam is then allowed to escape and a vacuum of 24 in. of mercury is produced. The purpose of this vacuum is to draw the sap, supposed to be dissolved by the steaming, and moisture out of the wood. The vacuum is maintained for at least ½ hour. Zinc chloride is then admitted and a pressure of 150 to 160 lb. per square inch is applied and maintained until the desired absorption is obtained. The amount of solution injected is equivalent to ¼ lb. of dry soluble zinc chloride per cubic foot of timber. When admitted to the cylinder the solution must be at a temperature of 160° to 170°F. The solution must be slightly basic and must contain no free acid. The percentage absorbed in the treatment is determined from an analysis of borings taken from time to time from at least six ties of the same run. The holes left by the auger are tightly plugged with creosoted plugs. After a treatment of this kind the timber must be allowed to stand until thoroughly dry before it is used.

The chemical used in the treatment is soluble in water and the benefit derived from the treatment depends upon the location where the timber is used. If exposed to the action of rain or if placed in a damp location the chemical will in time be leached out of the wood and will entirely disappear. Few European railways now use this method of treatment. Because of the liability to render the timber brittle there is a prejudice against using timber thus treated in structural work. Many timber-treating experts are of the opinion that much better results would be obtained if ½ lb. of the dry chemical per cubic foot of timber was used instead of ¼ lb., as is now the common practice.

91. Creosote and Zinc Chloride Combined.—Two processes, the Card process and the Allardyce process, are now being used in America for giving a combined treatment of creosote and zinc chloride. The first named is the more extensively used of the two. The object of both is to obtain an efficient treatment at a less cost than for straight creosote. A similar mixture is used in Germany in the Rutgers process, from which Card's process was really developed.

In the Card process a mixture consisting of about 80 per cent. zinc chloride solution and 20 per cent. creosote is used. Air-seasoned timber is run into the cylinder, a vacuum of 22 to 26 in. is drawn for about 1 hr., the vacuum is released and the treating mixture is let into the cylinder at a temperature of 180°F. The pressure is raised to 125 lb. and maintained for 3 to 5 hours. The mixture must be constantly agitated to prevent a separation of the oil and water in the liquid. This is accomplished by drawing the mixture from three places at the top of the cylinder and returning it through a perforated pipe running lengthwise in the bottom of the cylinder, thus maintaining a constant circulation through the cylinder. There is some doubt as to whether the ingredients remain mixed after entering the wood. The process is being used at about six treating plants.

In the Allardyce process a 4 per cent. solution of zinc chloride is forced into the wood at a pressure of about 130 lb. The cylinder is then drained and recharged with creosote under a pressure of about 180 lb. The penetration of the creosote is light, but it forms a waterproofing around the zinc chloride and prevents the latter from so readily being leached out. Better results are obtained if the timber is removed from the cylinder, air-dried and then treated with creosote. This considerably increases the cost of the treatment. The process is in partial use at two treating plants.

92. Kyanizing.—The first recorded use of bichloride of mercury or corrosive sublimate as a wood preservative was in 1705, by Homberg, in France. In 1832 Kyan first patented the treatment. This chemical is the strongest antiseptic of all metallic salts, is very poisonous, coagulates albumen, and attacks iron. It has been tried by the English and Dutch governments on timbers used in sea-water as a protection against marine worms, but in every case where used in water, particularly sea-water, it has been a failure. Some spruce is treated in this way in the New England States. If the timber is used in a dry location the treatment is satisfactory. The timber is allowed to soak in a solution of 1 lb. of bichloride to 8 or 10 gal. of water at atmospheric temperature and pressure. The period of immersion is determined by allowing 1 day, plus a day for each inch in the thickness of the timber. The treatment is being used at two small plants.

93. Open-tank and Brush Processes of Treating.—The brush process is a surface treatment in which the solution is applied to the surface of the timber with brushes or mops. It is used quite extensively in timber-construction on surfaces which will be in contact with the earth, and is generally applied after the timber is framed.

The brush system was the first ever used and it was in this way the ancients applied the preservatives to their wooden statues. It is generally observed that timber in a vertical position will outlast timber placed horizontally, under similar conditions. By mopping the tops of horizontal members, such as the caps of trestle-bents, with an antiseptic non-drying oil, checking will be reduced and decay retarded.

The first timber treatments of modern times were applied by the open-tank process. This process has an extensive use in treating timbers for various structural purposes. The open-tank process as now applied is as follows: A horizontal open-top metal or metal-lined wood tank, ranging in size from 3 to 4 ft. wide, 4 to 40 ft. long and 3 to 4 ft. deep is filled with the treating solution. The solution is kept above the boiling point of water by means of steam-coils in the bottom of the tank. As the timber is immersed in this hot bath the moisture in the wood is vaporized and forced out by the expanding air in the wood-cells. Seasoned timber contains about 50 per cent. of air by volume. As air expands $\frac{1}{273}$ its volume for each rise of 1°C. it will expand about one-third its volume for a change from 20°C. to 100°C., which is about the range of temperature in the treatment. After the timber has been in the hot bath a period ranging from 15 min. to 4 hr. it is removed and placed in a cold bath. In cooling, the air in the timber contracts and draws the preservative into the wood. By varying the duration of immersion in the hot and cold baths, particularly the cold bath, the amount of absorption can be somewhat controlled. It has also been attempted to treat green timber by this process, but the results are not satisfactory. Variations of this treatment are to soak the wood only in a cold solution or to immerse it for a short time only in the hot solution.

The advantages of the open-tank process are, (1) the equipment necessary is simple and the plant can be made portable; (2) low first cost of plant and low cost of operation; (3) the portions of the timber most likely to decay can be treated, as for example the butt end of poles and posts. However, it should be clearly understood by anyone contemplating the use of timber treated by the open-tank process that it is in no way a substitute for any of the pressure processes, that the results obtained by it are only temporary and that it should be used only where cheapness

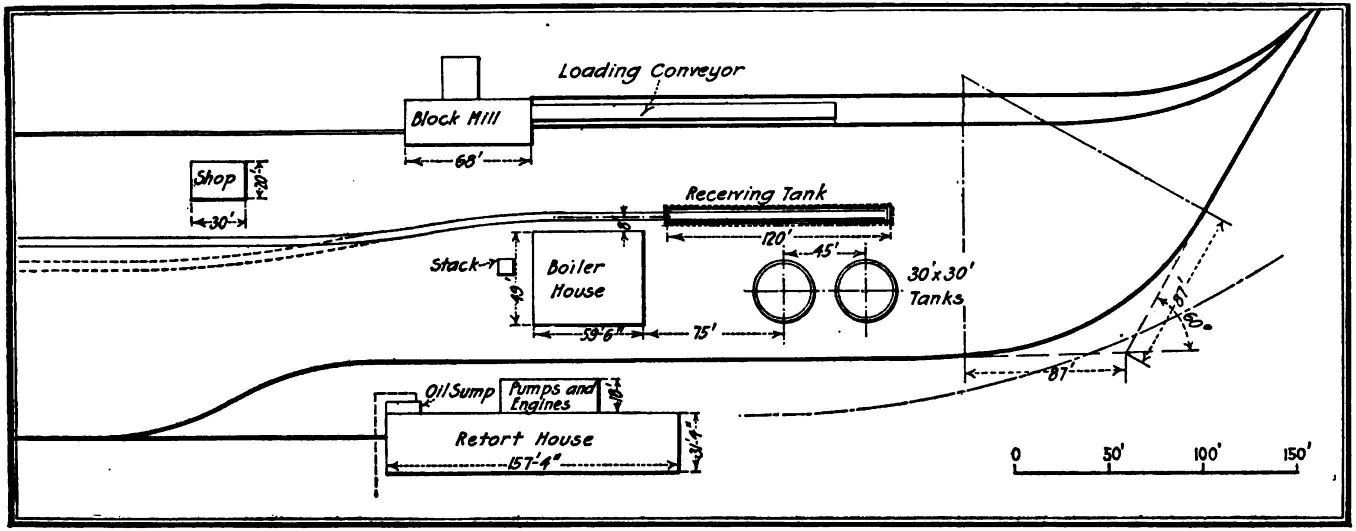


Fig. 35.—Plan of the wood-preserving plant of the Canada Creosoting Co. Ltd., Trenton, Ont.

is the controlling factor. The benefit of a brush treatment is, of course, even less than that of an open-tank treatment.

Creosote and several preparations known under the trade names of Carbolineum, Aczol, Locustine, Spiritine, etc., are used in the brush and open-tank processes. Carbolineum is essentially a high grade of creosote. It is very expensive and hence can be used only in small quantities. Aczol is an aqueous solution of copper sulphate, zinc chloride and ammonia. Locustine is said to consist of a petroleum base combined with animal and marine oils and an antiseptic salt. Spiritine is a wood-tar creosote made from coniferous wood.

94. Wood-preserving Plants.—The modern wood-preserving plant is quite complex and its first cost is considerable. Though the design of different plants varies more or less, the general features are similar and an idea of the complexity of the machinery required can be had from the following description of the plant at Trenton, Ont., which has been recently completed and embodies the very latest improvements in timber-treating equipment. Figure 35 is a plan of the plant, showing the arrangement of buildings and tanks. Ties or timbers from the seasoning-yard are loaded on tram-cars, as shown in Fig. 36, and pushed into the cylinder by an electric locomotive. Each car holds about sixty ties and the cylinder or retort, being 134 ft. long and 7 ft. in diameter, will take sixteen cars thus loaded. Figure 37 is an interior view of the retort-house. The cylinder (*A*) is built of riveted boiler-plate designed to withstand a pressure of 225 lb. per square inch. There is a door (*B*) at each end of the cylinder which is securely fastened and sealed after the timber charge has been run in. Figure 38 shows a charge of ties in the cylinder just before the end door is closed. Oil from the overhead

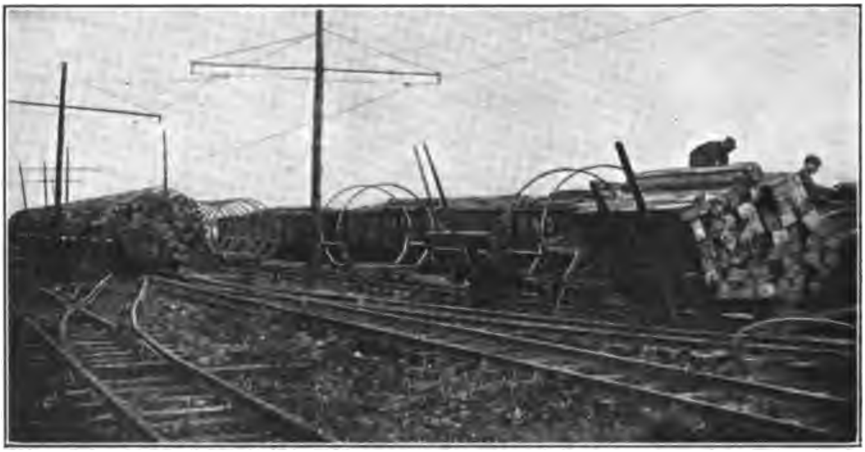


FIG. 36.—Tram-cars for charging cylinder with ties.

tank (*E*), Fig. 37, is then admitted to the cylinder and by means of steam-pumps additional oil is forced in until the pressure is sufficient to thoroughly impregnate the wood, ranging from 100 to 180 lb. The temperature of the liquid is regulated by steam-coils in the bottom of the cylinder running its entire length. During the treating process the temperature is kept within the limits of 150° and 190°F. After the proper absorption has taken place the oil is drained from the cylinder into a depressed tank (*C*) from which it is raised to the overhead tank by a centrifugal pump (*D*). A vacuum of from 23 to 27 in. is then quickly created by means of a vacuum-pump and condenser, and is maintained for 1 to 1½ hr. The cylinder is again drained, the doors are opened and the charge is withdrawn. The pressure in the cylinder, the amount of the vacuum, and the time are indicated and recorded by a set of gages. The amount of oil in the overhead tank at all times is shown by a gage. The difference between its reading before and after a charge is treated gives the total absorption. This is checked by weighing the charge before and after treatment. The complete process used at this plant requires from 3 to 5 hr. for ties.

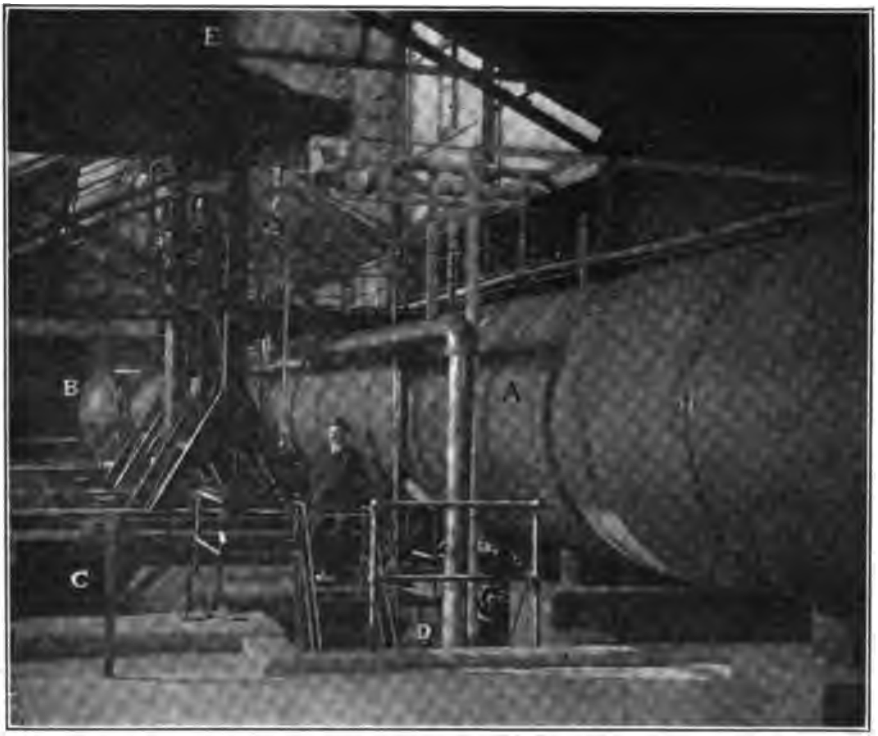


Fig. 37.—Interior of retort-house, Canada Creosoting Co. Ltd., Trenton, Ont.

One of the plants of largest capacity in America is that of the Atchison, Topeka & Santa Fe Ry. at Somerville, Texas, a general view of which is shown in Fig. 39. This plant is equipped with five cylinders, the ends of which can be seen in the illustration. These are 132 ft. long and 6 ft. 2 in. in diameter. There is, in addition, an experimental cylinder 12 ft. long and 48 in. in diameter designed for a working pressure of 400 lb. per square inch. An idea of the capacity of the plant may be had from the following figures which refer to material treated from Feb., 1906, to Dec., 1913:

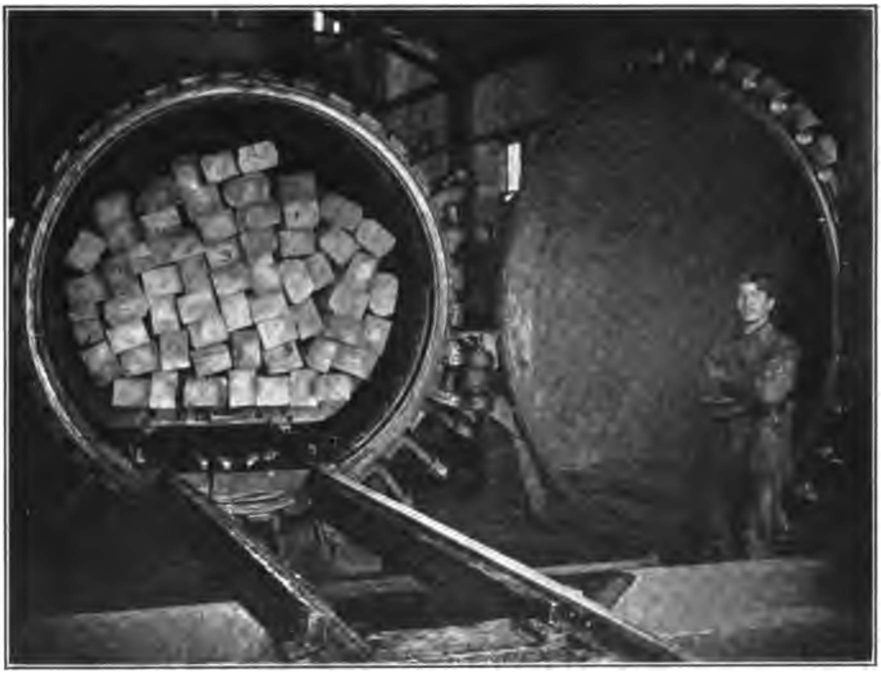


FIG. 38.—Cylinder charged with ties, ready to close door.

Cross-ties, 18,546,285.
Lumber, 99,917,777 ft., board-measure.
Piling, 4,588,210 lin. ft.

The buildings at this plant, and also at the Albuquerque plant of the Santa Fe, are absolutely fireproof, no wood being used in their construction.

95. Timber Piles.—There is always difficulty in renewing ties, ballast, and rails on track carrying dense traffic, but the difficulties of these renewals are insignificant to those encountered in renewing the piles and other parts of bridges and trestles. The railroads of America have a large mileage of timber trestles, only a very small percentage of which is constructed of treated timbers. The average railway has over 50 per cent. of all structures built of timber. Where solid foundations cannot be found it is necessary to support steel or concrete structures on piles. The question of obtaining timber for piles in the future is even more serious than that of obtaining ties, because it takes a much better tree to make a pile than a tie. The United States Forestry Bureau has said that it takes 190 years to grow a white cedar large enough for a telegraph-pole.

Several railways appreciate the economy resulting from the use of treated piles and bridge timbers and use considerable quantities of them. In some cases mechanical means are used to protect the piles from marine worms. On the Baltimore and Ohio Railroad, where a number of pile trestles have been constructed of creosoted timber, the treated material cost about 75 per cent. more than the untreated. On the Baltimore and Annapolis Short Line, a bridge was built across the Severn River several years ago, in which a casing of creosoted timber was built around each pile and the casing filled with clay to prevent the pile from being attacked by marine worms. The Union Pacific R. R. uses creosoted piles in all bridges and trestles of any size, and in all pile and trestle ballast-floor bridges creosoted caps and 4-in. planks also are used. On the Gulf, Colorado & Santa Fe Ry. treated timber has been used in trestles for several years. The first treated timber used was treated with zinc chloride, but recently all bridge timber has been treated with creosote. The Boston and Maine R. R. uses a brush treatment on timber bridges. On the Texas and Gulf Railway all material for permanent pile and trestle bridges is creosoted. Creosoted piles have been used on the Southern division of the Louisville & Nashville R. R. since 1876.

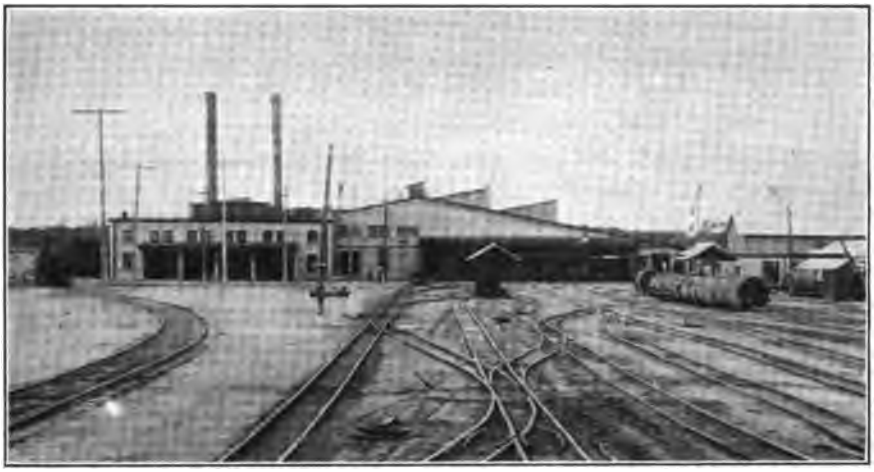


FIG. 39.—Wood-preserving plant of the Santa Fe at Somerville, Texas.

Other railways which use creosoted piles and other bridge timber to some extent are the Atchison, Topeka & Santa Fe, Illinois Central, and El Paso Southwestern System. The Lake Shore & Michigan Southern Railway uses carbolineum avenarius on all important timber structures where the timber comes in contact with the earth or with other timber. At one time the Atchison, Topeka & Santa Fe Ry. used caps treated with zinc chloride, but it was found that after such treatment they were very easily broken and the treatment was abandoned.

In most cases where piling and other submerged timber is subject to the attack of marine borers entire reliance for protection of the timber is placed on the creosote treatment. However, a much heavier treatment is required than is ordinarily given timber for other purposes. From 20 to 24 lb. of creosote per cubic foot of timber is generally specified. On the Louisville & Nashville R. R. it was found that after creosoted piles were in the water for a number of years the effect of the creosote diminished so that the worms eventually attacked the piles. The same road has used the following mechanical protection to piles in sea-water: (1) incasing the piles in a casement of rich concrete about 6 in. thick; (2) sliding vitrified bell and hub sewer-pipe over the pile after it is driven and filling the annular space with sand.

In 1875 the Santa Fe bought a number of creosoted piles to be placed in the trestle across Galveston Bay, Galveston, Texas, but no record was kept of the method of treating or of the amount of oil injected. In 1895 the trestle was reconstructed and the results of the first creosoted piles were so satisfactory that new creosoted piles were used in the reconstruction. At the time of reconstruction the old piles were left standing but no use was made of them in the new structure. In 1912 the causeway across the bay was opened and the trestle dismantled. The piles driven in 1875 had been standing in the water 38 years, though they were in service only 20 years. On examining them it was found that the portion exposed to air had almost entirely lost all outward trace of creosote. Piles which had been driven to place with no cut-off showed the heart-wood sound, although only 50 or 60 per cent. of the wood had been penetrated by the treatment. Where the butt had been cut off after the pile was driven, the heart-wood was badly decayed in every case. In some instances the water sections of the piles were in almost perfectly sound condition, but most of these sections had been attacked by Teredo and Limnoria. In rebuilding the trestle in 1895 all piles used, except 110 red cedar, were long-leaf yellow pine, treated with 24 lb. of creosote per cubic foot of timber. The piles were treated green. The treatment consisted of steaming the timber 24 hr. at a pressure of 55 lb. and for 12 hr. at a pressure of 47 to 50 lb. A vacuum was then maintained for 4 hr. after which the cylinder was filled with creosote oil and maintained under pressure until the absorption of 24 lb.

per cubic foot of timber had taken place. The red cedar piles were given only a light injection of creosote. When all piles were pulled in 1912 less than 10 per cent. of those driven in 1895 and in service over 17 years were found to be unfit for use in other work. Borers had attacked some of the piles and apparently had gained entrance through knots. This seems to be due to the fact that knots are high in resin and resinous wood will take the treatment very poorly. In untreated piles the borers do not first attack the knots, and the fact that they entered the creosoted piles through knots indicates that they did so to avoid the creosote. All timber high in resin was the worst attacked. Even though the cedar piles were treated with less creosote than the pine they had been attacked but very little by the borers.

96. Life of Timber Piles.—The life of untreated piles, as given in the 1908 Proceedings, American Railway Bridge and Building Association, was as follows:

White oak or bur-oak,	average of 10 railways,	average life 10 years.
White cedar,	average of 6 railways,	average life 17 years.
Red cedar,	average of 2 railways,	average life 12 years.

The life of creosoted piles is indicated by the following authentic record: (1) Piles driven in the trestle of the Santa Fe across Galveston Bay in 1875 (see preceding article); in service 20 years; heart-wood sound in many after being in place 38 years. (2) Over 90 per cent. of the piles driven in 1895 at the same place as (1) were fit for redriving when pulled after being in service 17 years. (3) Piles driven in 1876 in the trestle of the Louisville & Nashville R. R. across Pascagoula Bay, Miss., showed no signs of failure until first attacked by Teredo in 1912; they were still in service in 1914 and were sound as to rot. (4) Piles treated at Norfolk, Va., and driven in Hampton Roads near Newport News, Va., in 1882–83, were sound and in service in 1915. (5) Piles treated at Slidell, La. driven in 1883 in the 6-mile trestle of the New Orleans and Northeastern Railroad across Lake Pontchartrain, La., were still in service and sound in 1915.

That the treatment can be applied with similar results to poles is indicated by the fact that a number of telephone-poles treated at Norfolk, Va., and installed by the American Telephone and Telegraph Co. in 1898, were sound and still in use in 1915.

97. Strength of Treated Timber.—During the years 1904–1905 the United States Forestry Bureau made extensive tests to determine the effect of different treating processes upon the strength of timber. The following conclusions were drawn from these tests:

1. A high degree of steaming is injurious to wood in strength and spike-holding power. The degree of steaming at which pronounced harm results depends on the quality of the wood, its degree of seasoning,

the intensity of the steam pressure and the duration of application. For loblolly-pine the safe pressure limit is 30 lb. for 4 hr., or 20 lb. for 6 hr.

2. The presence of zinc chloride will not weaken wood under static loading but the wood is rendered somewhat brittle under impact.

3. Creosote in itself will not weaken wood.

From the results of recent tests made by the United States Forest Service, to determine how the strength of bridge stringers is affected by commercial creosote treatments the following deductions were made:[1]

1. Timber may be very materially weakened by preservative processes.

2. Creosote in itself does not appear to weaken timber.

3. A preservative process which will seriously injure one timber may have little or no effect on the strength of another.

4. A comparison of the effect of a preservative process on the strength of different species should not be made, unless it is the common or best adapted process for all the species compared.

5. The same treatment given to a timber of a particular species may have a different effect upon different pieces of that species, depending upon the form of the timber used, its size, and its condition when treated.

At a Pacific Coast plant an unusually severe treatment, consisting of a preliminary steaming at a temperature of 330°F., is given Oregon red fir piles. From tests made in 1914 to determine the effect of the treatment upon the strength of the timber, the following conclusions were drawn:[2]

1. The depth of penetration of the creosote is about proportional to the depth of sap-wood.

2. The heart-wood is almost impervious to treatment.

3. The depth of penetration is the same at the large and the small end of the log.

4. The injury to the wood-fiber, due to the method of treatment, is not alone in the fiber penetrated by the creosote but extends throughout the entire timber.

5. The transverse strength of the timber is decreased about 42 per cent. due to the steaming process.

6. The compressive strength perpendicular to the grain is decreased about 32 per cent.

7. The compressive strength parallel to the grain is decreased about 27 per cent.

8. In general, the strength of Oregon fir after treatment by the severe process used for Oregon fir piling at that particular plant is only about two-thirds of its original strength.

[1] Bulletin No. 286, United States Dept. of Agriculture, Sept. 27, 1915.

[2] Bulletin 168, American Railway Engineering Association.

CHAPTER VIII

RAILS

98. Early History.—The rail has been given more study than any or all other parts of the track. Its development has followed closely that of the railway. The first rolled rails used in England consisted of pieces of iron straps laid on longitudinal stone or timber sills placed in continuous parallel lines. These rails were of a rectangular cross-section ½ in. thick by 2 in. wide and about 15 ft. long. They were held in place by small spikes driven in cedar plugs placed in holes drilled in the stone sills, or were driven directly into the wooden sills. The earliest types of metal rails are shown in Fig. 40, *a*, *b*, and *c*.

In 1820 a modification of the bar rail was patented in England by Birkenshaw. This rail had a thin web with top and bottom enlargements, and was the forerunner of the present English double-head or bull-head rail. It was not self-supporting and had to be carried in cast-iron chairs.

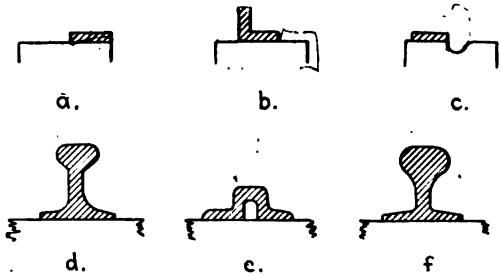


Fig. 40.—Early types of rails.

The first 10 miles of the Philadelphia and Columbia Railroad were laid with strap or bar rails. The next 71.8 miles were laid with a chair-supported rail similar to that of Birkenshaw. However, most of the railways at first used strap rails. In 1830 there were 23 miles of railway in operation in America. In 1840 this had increased to 2818 miles in the United States and 16 miles in Canada. All the early rails were imported from England or Wales, there being no rolling-mills in this country. The section of strap rail first used proved to be too light and was increased to 1½ by 3 in. Under a slight increase in speed and a driving-wheel load of 3 or 4 tons, strap rails gave much trouble by turning up at the ends. Accidents on these rails were so numerous between 1840 and 1850 that their use was discontinued in New York State in 1844.

The first rail approximating the present T rail was designed in

America, in 1830, by Robert L. Stevens, Chief Engineer of the Camden and Amboy Railroad. These rails weighed 36 and 40 lb. per yard and were rolled in 16-ft. lengths. The section of this rail is shown at (*d*), Fig. 40. The rail was also rolled to the section shown at (*f*). This was called a "pear-shaped" rail. A hollow U-shaped rail, (*e*), was invented in the United States in 1834 by Strickland. This is sometimes called a bridge-rail but the term "bridge-rail" rightly belongs to any rail designed to rest on intermittent supports, in distinction to a rail designed to rest on a continuous longitudinal sill.

Many pear-shaped rails were imported from England. Some, rolled from refined iron, lasted a number of years under light loads, but when the wheel loads increased to 5 or 6 tons, and the speed of trains increased to 25 and 30 miles per hour the rails commenced to break or split in the head. Broken rails became so numerous in the sixties that several railways tried the Booth steel-capped rail, which had a top surface of ¼ in. of crucible steel rolled on to a wrought-iron stem. As the steel was not welded to the iron the rail proved a failure.

The first Bessemer steel rails were rolled in England about 1860. In 1863 several trial lots were imported by American railways. These weighed 56 to 58 lb. per yard, were 4 in. high and had a comparatively thin head and thick base. It was found that in places of severe service one of these would outlast 10 to 15 of the best iron rails. In 1864 the Erie Railroad ordered 1000 tons of Bessemer rails from Sheffield, Eng., at a cost of $120 per ton.

The first steel rails made in America, six in number, were rolled in 1865 at the North Chicago Rolling Mill from ingots of Bessemer steel cast at the Wyandotte mills, near Detroit. These rails were placed in the track of the Chicago and Northwestern Railroad and are known to have carried traffic over 10 years, but there is no record of when they were finally removed. The first rails rolled in America were patterned after those rolled in England and had a height of 4 to 4½ in. and a comparatively thin head and thick base.

99. Development of the Present Sections.—After the close of the Civil War railway development again commenced in the United States. About 1870 a committee of engineers recommended changing the section by making the base thinner and adding about 50 per cent. of metal to the head. In 1865 Ashbel Welsh designed a T rail having a rounded head similar to English practice at that time, but in other respects similar to the present American section. Some of these rails were laid in 1867. The excellent results expected from rails with thicker heads were not realized and in 1873 a Committee was appointed by the American Society of Civil Engineers to investigate and report on the form, weight, manufacture, and life of rails. The final report of the Committee was made in 1876. At that time but few steel rails were in use, so that the report dealt almost exclusively with iron rails. During the early seventies the quality

-B rail sections		Table 10. R. E. and miscellaneous rail sections							
		R. E.			P. S.		C. P. R.	N.Y.C.&H.R.R.R. (Dudley)	
90 lb.	100 lb.	100 lb.	110 lb.	120 lb.	85 lb.	100 lb.	85 lb.	100 lb.	105 lb.
4 49/64	5 9/64	5 3/8	5 1/2	5 3/4	4 5/8	5	5	5 1/2	5 1/2
5 17/64	5 41/64	6	6 1/4	6 1/2	5 1/8	5 11/16	5 1/8	6	6
2 9/16	2 21/32	2 11/16	2 25/32	2 7/8	2 1/2	2 43/64	2 7/16	3	3
9/16	9/16	9/16	19/32	5/8	17/32	9/16	9/16	19/32	5/8
2.445	2.625	2 3/4	2 53/64	2 59/64	2 27/64	2 81/128	2 19/64	2.93	2.85
2 11/32	2 1/2	2 31/32	3 1/8	3 1/4	2 13/64	2 31/64	2 11/32	3 1/8	3 1/8
5/16	5/16	3/8	3/8	3/8	1/4	5/16	3/8	1/2	1/2
5/16	5/16	5/8	5/8	5/8	1/4	5/16	3/8	5/16	1
3/8	3/8	3/8	3/8	3/8	· 7/16	7/16	1/4	5/16	5/16
2 5/8	2 55/64	3 9/32	3 13/32	3 17/32	2 15/32	2 25/32	2 11/16	3 13/32	3 13/32
1 1/32	1 5/64	1 1/16	1 1/8	1 3/16	1	1 3/32	1	31/32	31/32
1 39/64	1 45/64	1 21/32	1 23/32	1 25/32	1 21/32	1 13/16	1 7/16	1 5/8	1 5/8
12	12	14	14	14	10	10	8	14	14
13°	13°	4:1	4:1	4:1	15°	15°	4:1	4:1	4:1
13°	13°	4:1	4:1	4:1	13°	13°	4:1	4:1	4:1
3°	3°	1:16	1:16	1:16	0°	Top width 2 1/2	Top width 2 1/2	1:16	1:16
89.5	100.5	101.49	110.36	120.87	86.4	101.6	85.1	100.0	104.73
3.56	3.95	3.80	4.04	4.40	3.57	4.09	3.06	4.01	4.20
40.1	40.2	38.2	37.4	37.1	42.2	41.0	36.68	40.8	40.9
1.70	1.89	2.25	2.49	2.69	1.51	1.85	1.865	2.31	2.52
19.2	19.2	22.6	23.0	22.7	17.8	18.6	22.37	23.5	24.5
3.61	4.01	3.90	4.29	4.76	3.39	4.03	3.415	3.51	3.56
40.7	40.6	39.2	39.6	40.2	40.0	40.4	40.95	35.7	34.6
8.87	9.85	9.95	10.82	11.85	8.47	9.97	8.34	9.83	10.28
32.3	41.3	49.0	57.0	67.6	29.1	41.9	29.49	48.5	50.02
11.45	13.70	15.1	16.7	18.9	10.77	13.71	10.42	15.81	15.89
13.21	15.74	17.8	20.1	23.1	12.02	15.91	12.84	16.55	17.53
3.64	4.20	4.92	5.27	5.71	3.44	4.20	3.54	4.93	4.88
1.29	1.39	1.52	1.55	1.59	1.27	1.37	1.21	1.61	1.55

(Facing page 128)

of iron rails was very poor. The rails cracked, laminated, and the top flaked off destroying the running surface. The use of steel rails was thus forced upon the railways.

About 1874 R. H. Sayre designed a rail having a head with top corners of large radius and sides sloping outward from the top. The flare of the sides was intended to reduce the wear of the head caused by the wheel-flanges. In 1883 the Lehigh Valley R. R. adopted a 76-lb. Sayre rail having a flare of 10°. In later sections the flare was reduced to 5° and finally the railway adopted the American Society of Civil Engineers section.

A second committee of the American Society of Civil Engineers was appointed in 1887 to consider the relation between the sections of the rail and wheel. The final report of the committee was made in 1889 and in the following year a third committee was appointed to draft a set of standard sections for rails of various weights. In 1893 the final report of the committee was adopted by the society. These sections are known as the A. S. C. E. standard sections and vary in weight by intervals of 5 lb. from 40 to 100 lb. per yard. The sections met with immediate favor by the railways and a few years afterward about two-thirds of all rails rolled were A. S. C. E. sections. The distinctive feature is that, for any weight, the height and width of base are equal. The distribution of metal is proportionately the same in all weights, 42 per cent. being in the head, 21 per cent. in the web, and 37 per cent. in the base. When these sections were designed no rails heavier than 80 lb. had been rolled and the 85- to 100-lb. sections were designed theoretically. The desirability of a standard section can be appreciated from the fact that before the A. S. C. E. sections were introduced about 300 different rail sections were in use. This required an unnecessarily large investment in rolls by the manufacturers. All details of the A. S. C. E. sections from 55 to 100 lb. are shown in Table 7.

The light A. S. C. E. sections have been satisfactory, but this has not been the case with sections heavier than 85 lb. It is not surprising that such is the case, since, 20 years after the A. S. C. E. sections were adopted, the maximum weight of rail had increased about 25 per cent. while the maximum drive-wheel loads had increased about 60 per cent. Realizing the necessity for improving the heavier rail sections, the American Railway Association appointed a committee to recommend standard sections for rails and wheels. The final report of the committee was made in 1908. Two types, known as the A. R. A.-A and the A. R. A.-B sections, were adopted by the association. The sections vary in weight by 10 lb. from 60 to 100 lb. per yard. The principal differences between these and the A. S. C. E. sections are that the A. R. A. sections have a narrower and heavier base and lighter head. Type A has a comparatively shallow head, wide base, and a thinner flange and greater height than type B, and was designed to give greater transverse strength. All details of the different sections of these two types of rails are given in Tables 8 and 9. More type A rails are used on the prairie roads of the west. With this section more of the load is carried by the rail and less by the ties and ballast. Type B rails seem to be preferred by the eastern roads having heavy traffic and a large percentage of curvature. The shallow section of type B gives more flexibility and transfers more of the load to the ties and ballast. Advocates of this section claim that the pounding of the wheels under heavy traffic would tend to crush the head of the stiffer A section.

In 1907 a committee of engineers of the Pennsylvania Railroad designed an 85-lb. rail and a 100-lb. rail for use on that system. These sections are known as the "P. S." (Pennsylvania System) sections, and have a heavy head, narrow base, and thick flanges. The head of the 85-lb. section has vertical sides, while that of the 100-lb. section has flaring sides. This difference was a result of fixing the width of head at 2½ in. and fixing a minimum width for the bearing surface or fishing surface under the head for supporting the splice-bars. The 100-lb. section is shown in Fig. 41 and the details of both sections are given in Table 10. The Dudley rail of the New York Central Lines has sloping sides for all sections. The slope is $\frac{1}{16}$ to 1. Details of this section are given in Table 10.

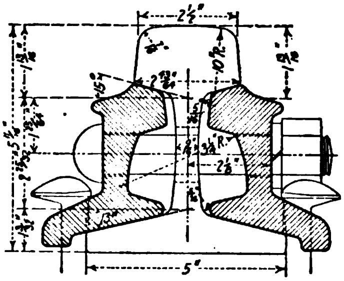


FIG. 41.—100-lb. P. S. rail section of the Pennsylvania Railroad.

After several years of service the A. R. A. sections have not proved entirely satisfactory. At the time these sections were recommended, the American Railway Association referred the whole subject of rail study to the American Railway Engineering Association with the request that, after carefully comparing the results of types A and B, a single section be recommended. In 1915 the Rail Committee of the American Railway Engineering Association made their recommendations for the adoption of a single type of section. They are known as the "R. E." sections, and are for weights of 100, 110, and 120 lb. All details of these sections are given in Table 10. The 90-lb. A. R. A.-A section was recommended for adoption as the single-type standard for that weight. While working out these sections two things having a direct bearing on economy in other track material were considered. These were the use in sections of more than one weight of (1) a common fishing space or distance from top of base to bottom of head, and (2) a common width of base. A common fishing space would considerably reduce the number of splice-bars of different sizes which it is necessary for a railway to keep in stock. A common width of base would make the base uniform, would permit of a uniform boring of ties for spikes and, by allowing a uniform punching of tie-plates, would reduce the number of differently punched tie-plates which must be kept in stock. The committee decided that these features could not be made common to sections of different weights without sacrificing the strength of the rail.

European railways use a T rail of the type invented in England in 1836 by Charles Vignoles. The rail of this type used on the Paris, Lyons and Mediterranean Railway is shown in Fig. 42. The T rail has met with little favor in England. The double-head or bull-head rail developed from the rail invented by Birkinshaw is the standard on English railways. In Fig. 43 is shown the 80- and 100-lb. sections of the English bull-head rail. This section is known as the British Standard. The double-head rail was first designed with the idea that after one head became badly worn, the rail could be reversed and an equal service obtained from the other head. The indentation of the lower head by the rail-chairs made a very rough-riding track when the rails were reversed. In 1858 the bull-head rail was introduced. The reversible feature was abandoned and the lower head was made only large enough to form a seat in the chair and a bearing for the wooden key or wedge which holds the rail in the chair. The disadvantage of this type of rail is that it must be supported at every cross-tie by a heavy cast-iron chair.[1]

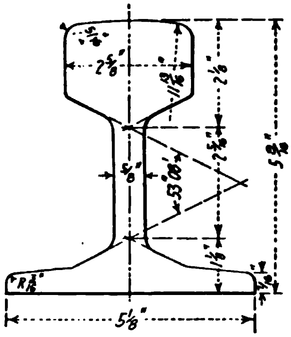
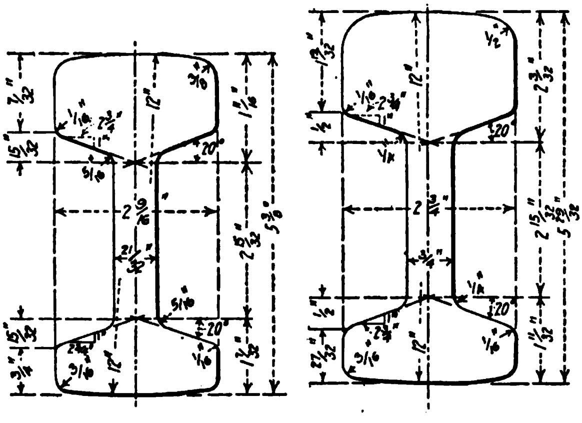


FIG. 42.—Vignole rail of the Paris, Lyons and Mediterranean Railway.



80-lb. per Yd., B. S. Section No.80 100-lb. per Yd., B.S. Section No.100

FIG. 43.—British Standard bull-head rails.

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[1] For a description of this chair see Art. 151, page 195

100. Chemical Composition.—With the exception of iron, the five most important elements in steel are carbon, manganese, phosphorus, silicon and sulphur. A steel containing these elements is called a carbon steel. The effect of carbon upon the physical properties of rails is to increase the strength and resistance as the percentage of carbon increases up to about 0.80 or 0.85 per cent. For a higher percentage of carbon the strength and resistance remain about as at 0.80 or 0.85 per cent. The ductility decreases continuously with the increase in carbon. By using a high percentage of carbon in order to get a hard steel, there is danger of rendering the steel brittle unless the other chemical components are properly proportioned and the process of manufacture is carefully controlled.

Phosphorus is one of the most troublesome constituents because it hardens steel more rapidly than does either carbon or silicon. It makes the steel brittle by increasing its hardness and decreasing its toughness. Steel high in phosphorus is sensitive to high heat and should be rolled as cold as possible. As no phosphorus is eliminated in the Bessemer process, only ores low in phosphorus can be used. Practically all rails rolled prior to 1903 were Bessemer steel. From 1890 to 1898 it was possible to obtain ores which would make Bessemer rails of 0.06 per cent. phosphorus. After 1898 low-phosphorus ores became very scarce and the percentage of phosphorus in Bessemer rails increased to 0.10 per cent. The scarcity of these ores brought about the modern development and extensive use of the open-hearth process.

A small percentage of silicon hardens the steel. In this respect silicon stands between carbon and phosphorus. It has a tendency to prevent the formation of unsound ingots due to porous metal. In moderate proportions it does not render the steel brittle.

Sulphur is objectionable because it causes the formation of small seams or cracks during the process of rolling. These close up during later stages of the rolling and are not perceptible in the finished rail, but are often the starting place for ultimate failure. Sulphur renders metal "red-short," that is, the metal must be worked at a high temperature. As the heat approaches a red color the metal is difficult to work and cracks are more liable to form.

A small percentage of manganese produces a smooth surface and good rolling qualities. It increases the tensile strength and reduces the ductility. Its influence on the steel varies with the percentage of carbon, becoming more pronounced in high-carbon steel. It tends to counteract the red-shortness produced by sulphur and the cold-shortness produced by phosphorus.

The chemical analysis of a 100-lb. rail broken on the Pennsylvania Railroad, Feb. 2, 1912, showed the following percentages of these five elements: carbon 0.80 per cent., manganese 0.60 per cent., silicon 0.16

per cent., sulphur 0.023 per cent., phosphorus 0.029 per cent. Physical tests showed an elastic limit of 60,050 lb. per square inch.

The 1915 specifications of the American Railway Engineering Association for the chemical composition of steel rails are as follows:

"The chemical composition of each heat of the steel from which the rails are rolled shall be within the following limits:

	Per cent. for Bessemer process		Per cent. for open-hearth process	
	70 lb. and over but under 85 lb.	85–100 lb. inclusive	70 lb. and over but under 85 lb.	85–100 lb. inclusive
Carbon	0.40 to 0.50	0.45 to 0.55	0.53 to 0.66	0.62 to 0.75
Phosphorus not to exceed	0.10	0.10	0.04	0.04
Manganese	0.80 to 1.10	0.80 to 1.10	0.60 to 0.90	0.60 to 0.90
Silicon not less than	0.10	0.10	0.10	0.10

"When other acceptable deoxidizing agents are used, the minimum limit for Silicon will be omitted."

Specifications formerly limited the percentage of sulphur to about 0.075 per cent. in Bessemer rails and 0.06 per cent. in open-hearth rails, but sulphur is omitted from the above specifications.

Copper and arsenic, also, are often present in rail steel. Copper in small quantities has but little effect upon the mechanical properties of steel. Arsenic up to 0.60 per cent. increases the tensile strength, lowers the elastic limit, and decreases the elongation.

101. Alloy-steel Rails.—For some years past, several special steel alloys have been used experimentally for rails, to give the steel special mechanical qualities such as high resistance to shock, a high elastic limit, and a high resistance to wear. The alloys used are manganese, titanium, nickel, and chromium. They may be used either in the Bessemer or in the open-hearth process.

Manganese-steel rails have been manufactured since about 1908, but only since about 1910 or 1911 have they been rolled commercially. Among other railways, the Chicago and Northwestern and the Delaware, Lackawanna and Western are using them on curves, where the wear is the most severe. The chemical composition of the rails manufactured by the Manganese Steel Co., New York, is:

Carbon	0.95 to 1.35 per cent.
Phosphorus	not over 0.10 per cent.
Manganese	10.50 to 15.00 per cent.

The Norfolk & Western Ry. reports excellent results from a rail the composition of which was carbon 0.77, phosphorus, 0.06, manganese 9.93, silicon 0.25, sulphur 0.038. Some other trials indicate worse wear than ordinary Bessemer rails. Also, Bessemer rails with ferro-titanium have given conflicting results compared with ordinary Bessemer rails. Nickel and chromium-nickel have not given as good service as ordinary Bessemer. Several test-lots of basic open-hearth vanadium-steel rails were rolled in 1914 for test purposes. The composition was carbon 0.45 to 0.60, manganese 1.00 to 1.25, silicon over 0.10, phosphorus not over 0.05, sulphur not over 0.05, and vanadium 4 lb. per gross ton. Laboratory tests indicated that these rails were considerably stronger than carbon-steel rails.

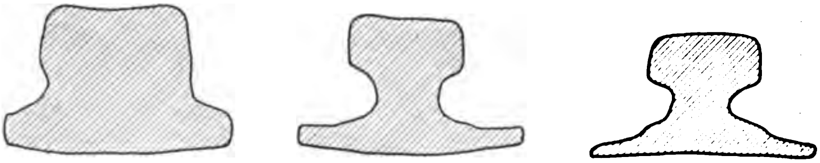
Alloy rails are expensive and the benefits are doubtful. It might be better to pay more attention to get a good quality of rails made of ordinary steel than to try to get rails made of special grades of steel. From 1910 to 1914 there was a steady decrease in the tonnage of rails rolled from alloy-treated steel, the 1913 tonnage being only about one-fifth and the 1914 tonnage about one-ninth that of 1910.

102. Manufacture.—The physical treatment of the metal during the manufacture of rails is at least of equal importance to the chemical composition. The best mill-practice of today in the manufacture of rails is as follows:

The well-purified and thoroughly mixed molten metal is poured into ingot molds. As soon as the metal has cooled sufficiently to solidify, the ingot is removed from the mold and placed in the soaking-pit where it is kept at a temperature of 1500° to 2000°F. When needed, it is taken from the soaking-pit and is rolled in a blooming-mill. By successive passes, the ingot is reduced to a bloom or bar about 8 by 8 in. square and 15 to 24 ft. long. The bloom is then cropped about 12 in. on the ends to cut off any unsound metal, and is cut in two to four pieces, according to the length of bloom and weight of rail to be rolled. The blooms go to the rail-mill where roughing-rolls and intermediate-rolls approximately shape the rail. The finishing-rolls give the rail its final section and form the name of maker, date, weight, and other necessary marks on the web of the rail. The hot rails are then cut to the proper length by a circular saw, so that when cool they will be 30 or 33 ft. long. The hot rails are given a camber of from 6 to 12 in., by a cambering machine (the actual amount of camber depending on the distribution of metal), after which they are placed on the cooling-beds, where cooling takes out the camber. When cooled, the rails go to the cold-straightening press where any kinks are taken out. The burr left by the saw is chipped off, the ends are filed, the rails are measured for length, drilled for bolt-holes, and are then placed on the inspection or shipping platform. Successive stages in the rolling of a rail are shown in Fig. 44.

The following is the general practice of thirteen rail-mills in the United States and two in Canada: The capacity of Bessemer converters ranges from 5 to 25 tons, the average being about 15. The capacity of open-hearth furnaces is from 35 to 100 tons. The size of ingot ranges from 18 by 19 in. to 23 by 29 in. at the bottom and the height from 67 to 82 in. The number of ingots is from 2 to 7 per heat for Bessemer and from 60 to 192 for open-hearth. The number of passes of the ingot in the blooming-mill is from 6 to 25. The average size of bloom is 8 by 8 in. The number of passes in the rail-mill is from 9 to 13. The total number of passes from ingot to rail is from 15 to 40, averaging about 25. Ordinarily, two blooms are cut from one ingot and from two to four rails are rolled from each bloom, depending upon the size of rail section. There has been little change for a number of years in the method of rolling rails.

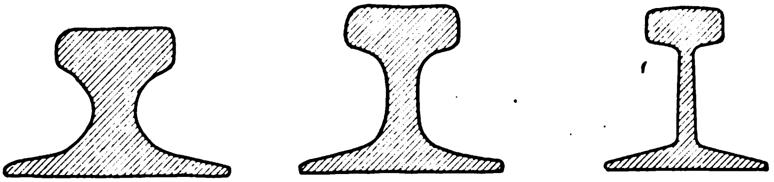
The production of open-hearth rails in the United States has steadily increased since 1903, when they were first rolled in any considerable quantity. The maximum output up to 1914 occurred in 1913. In 1914 the production of Bessemer rails was only 22 per cent. of the tonnage of open-hearth rails. The amount of Bessemer rails rolled has steadily decreased since 1906, in which year the total tonnage of all kinds rolled was the largest of any year for the period 1897–1914. In 1913 over 87 per cent. of rails weighing over 85 lb. per yard were rolled from open-hearth steel. No iron rails have been rolled since 1911. Electric rails were first rolled in 1909 and a small tonnage has been produced each year since.



Third Roughing Pass

Fifth Roughing Pass

Squabbing Pass



First Forming Pass

Second Forming Pass

Rail

FIG. 44.—Different stages in the rolling of a rail.

It was formerly thought that the temperature at rolling affected the mechanical properties of the rail, but recent experiments indicate that the temperature at rolling has little influence on the wear of the rail. The important considerations are to secure sound ingots, and to give each part of the rail, and the head in particular, a maximum amount of work during the rolling. The average temperature at which the ingot enters the blooming-mill is 1900°F. and the resulting rail reaches the hot-saw at about 1700°F.

103. Sound Ingots.—The most serious defects in rails result from unsound ingots. It is possible to produce sound ingots, but the ordinary method of casting ingots results in the formation of a large proportion of unsound metal at the top and often the defect extends entirely through the ingot. The unsoundness may be the result of (*a*) a funnel-shaped cavity or pipe at the top of the ingot; (*b*) a segregation of the impurities, such as manganese, phosphorus, silicon, slag, etc.; (*c*) cavities or blow-holes throughout the metal; (*d*) pits or disc-like cavities on the surfaces of the ingot in contact with the mold. It has also been demonstrated that, because of the oxidizing conditions existing in the soaking-pits, all surfaces of the ingot to a depth of about ¼ in. are decarburized so that this metal contains from 8 to 10 points lower carbon than the interior metal.

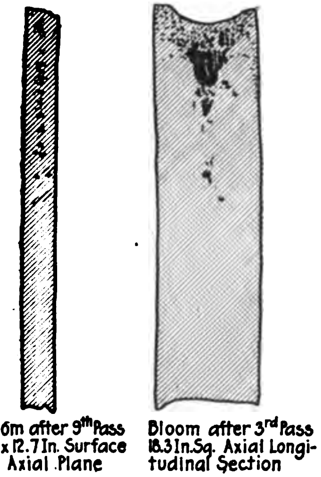


FIG. 45.—Unsound Ingots (Am. Ry. Eng. Assn.).

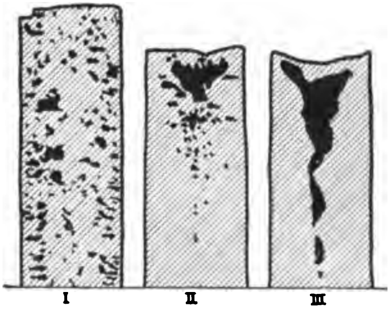


FIG. 46.—Upper portion of three small ingots—4 ins. square—made to illustrate and test the question of soundness and piping (Am. Ry. Eng. Assn.).

Pipes are caused by the contraction of the interior of the mass after the outside has solidified. Blow-holes are due to gas in the metal which should have been burned out in the furnace. Surface pits are caused by air being entrapped against the sides of the mold as the ingot is poured. Figure 45 shows two piped ingots which have been cut down the middle, one after the third and the other after the ninth blooming-pass. Figure 46 shows three other defective ingots cut down the middle; No. 1 shows blow-holes; No. 2 and No. 3 show pipes. Pipes and blow-holes are rolled out into cracks in the finished rail. These are on the interior of the rail and can be detected only by drop tests. A sufficiently large percentage of the ingot should be cropped to insure a discard of all unsound metal. This may mean a loss of 25 per cent. or more of metal. Surface pits are less serious than pipes or blow-holes, but also are rolled out into minute cracks which may ultimately cause failure of the rail.

A satisfactory and practical method of producing ingots thoroughly sound as to piping, one of the most serious of ingot defects, was invented by Sir Robert Hadfield of the Hecla Works, Sheffield, Eng. In this method the molten metal is poured into an ingot-mold having a metal collar lined with sand. An inch or so of molten slag is poured over the top of the metal and a layer of charcoal is placed over this. An air blast is turned on the charcoal, causing it to burn at a high temperature which keeps the upper part of the metal fluid and, as the lower part cools and contracts, molten metal from the top is sucked down by the contracting lower part and forced down by the ferro-static pressure of the fluid, so that all cavities which tend to form are at once filled. The metal must be free from gas as the method will not prevent the formation of blow-holes.

During 1914 a method for eliminating the defects resulting from surface pitting was introduced at the works of the Lackawanna Steel Co. The method is as follows:

The ingot is reduced to a bloom 8 by 8 in., the ends are cropped, and the bloom is run through the roughing-rolls for five passes. The rail is then about 75 per cent. finished. The bar is then started through two pinch-rolls, that part of the bar being uppermost which will form the bottom of the rail. Immediately beyond the first pinch-rolls are two large milling-rolls and, as the bar passes between them, from 1/32 to 3/64 in. of metal is milled from the top and bottom of the bar. The sides of the bar are not milled, but the milled surfaces are those which form the head and base of the rail and are where the small seams of the ingot surface are most objectionable.

104. Branding.—In order to be able to compare the service and failure of different kinds of rails it is desirable to know when and where each rail was rolled, whether the steel is Bessemer or open-hearth, the number of the heat, blow, or melt of steel, and the part of the ingot from which the rail was rolled. The specifications of a few railways require the ingot number, in addition, to be stamped on the rail. The rail rolled from the top portion of the ingot is designated as the "A" rail from that ingot. The rail from the next lower portion of the ingot is the "B" rail, and so on.

The marks on rails are produced in two ways, (1) by branding and (2) by stamping. The brand is cut into one of the rolls of the last pass and hence appears slightly raised at regular intervals on the web of the rail. Square block-letters and -figures about an inch high are commonly used. The month is generally shown by Roman numerals, as VII for July, and sometimes by a series of I's as IIIII for May. The number representing the heat and the letter to indicate the position of the rail in the ingot are stamped on the web of the rail while it is still hot, but after it is completely rolled and sawed to length. These numbers and letters are depressed while the brands are raised. The stamping may be done by hand or by machine and the stamp may or may not be repeated several times on the length of rail.

The following is taken from the 1915 specifications for branding, of the American Railway Engineering Association:

> "Rails shall be branded for identification in the following manner: (*a*) The name of the manufacturer, the month and year of manufacture, and the weight and type or section of rail shall be rolled in raised letters and figures on the side of the web. The type shall be marked by letters which signify the name by which it is known, as for example, as follows:"

"Sections of Am. Soc. of Civil Engineers	A. S. C. E."
"Sections of Am. Railway Association	R. A. A. R. A. B."
"Sections of Am. Ry. Eng. Association	R. E."

> "(*b*) The number of the heat and letter indicating the portion of the ingot from which the rail was made shall be plainly stamped on the web of each rail where it will not be covered by the joint-bars. The top rails shall be lettered 'A' and the succeeding ones 'B,' 'C,' 'D,' etc., consecutively; but in case of a top discard of from 20 to 35 per cent. the letter 'A' will be omitted, the top rail becoming 'B.' If the top discard be greater than 35 per cent. the letter 'B' shall be omitted, the top rail becoming 'C.'"
>
> "(*c*) Open-hearth rails shall be branded or stamped 'O-H' in addition to the other marks."

In some cases the letters "F. T." are added to indicate ferro-titanium steel.

The practice followed by individual mills in stamping the heat number and rail letter upon rails is given in Table 11.

105. Inspection.—The workmen who roll the rails are paid on a tonnage basis. Hence what they are principally concerned in is tonnage. The quality of the output is a secondary consideration to them. As long as the men are paid on this basis the best quality of workmanship will not be obtained. The first rails were bought by railways under the manufacturers specifications. Later, the specifications were prepared by the railways; but until recently these specifications were often a compromise between what the railway engineer wanted and what the manufacturer was willing to do.

In order to see that the method of manufacture follows the specifications, a railway must have expert inspectors at the mill to watch the rail through every step in the process of manufacture. There are several inspection bureaus which make rail-inspection a part of their business. In most cases the interests of the railway are best protected if one of these bureaus is engaged to do the inspecting, because these professional inspectors are familiar with the mill-practice at each plant, and by previous experience know where the greatest watchfulness is needed. A few rail-

TABLE 11.—INDIVIDUAL MILL-PRACTICE OF STAMPING STEEL RAILS

	Steel mill	Number of figures in heat number		Number of times heat number is stamped on each rail	Position and number of times rail letter is stamped on each rail	Side of rail on which heat number and rail letter are stamped
		Bessemer	Open hearth			
1	Algoma Steel Company...	One to five.	Generally four.	At least three times.	Rail letter usually omitted.	Unbranded side.
2	Bethlehem Steel Company	Five.	Five.	At least once.[1]	Follows the heat number.	Unbranded side.
3	Cambria Steel Company..	One to five.	Five.	At least twice.	Appears about six times.	Unbranded side.
4	Carnegie Steel Company (Edgar Thompson Works)	One to five.	Five.	At least three times.	Generally twice near one end.	Unbranded side.
5	Colorado Fuel & Iron Co..	One to four.	One to four.	At least twice.	At least once near one end.	Branded side.
6	Dominion Iron & Steel Co.	Four.	Four.	At least twice.	At least once near the end.	Unbranded side.
7	Illinois Steel Company (South Works).	One to five.	One to five.	At least twice.	Follows the heat number.	Unbranded side.
8	Illinois Steel Company (Garry Works).	Five.	Five.	At least twice.	Follows the heat number.	Unbranded side.
9	Lackawanna Steel Co.....	One to five.	One to five.	At least once.	At least once, generally near the heat number.	Unbranded side.
10	Lorain Steel Company....	Four.	Four.	Near one end of rail.	Usually omitted.	Unbranded side.
11	Maryland Steel Company.	One to five.	Four.	At least twice.[2]	Immediately after heat number.	Unbranded side.
12	Monterey Iron & Steel Co.	Four.	Four.	At least three times.	Immediately after heat number.	Unbranded side.
13	Pennsylvania Steel Co....	Either four or five.	Either four or five.	At least twice.	Immediately after heat number.	Branded side.
14	Tennessee Coal, Iron & Railroad Company.	Five.	Five.	At least twice.	Immediately in front of heat number.	Unbranded side.

ways are fortunate enough to have experts to direct the work and these railways can best look after their own interests at the mill.

A force of twelve to fifteen inspectors should be at the mill during the manufacture of an order of rails. These men must see that enough of the ingot is cropped to insure sound metal; that the specimens for the drop test are actually cut from the top of the ingot as specified; that the temperature, number of passes, and speed of rolls are as specified; that the borings for check analysis come from the ingot represented, etc. The finished rails are finally inspected and classed as No. 1 rails and No. 2 rails. No. 1 rails are those which are free from defects and flaws of any kind.

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[1] Generally near the center. A letter indicating a furnace is sometimes placed in front of the heat number.

[2] Should not be confused with a character, which may show immediately in front of the heat number.

No. 2 rails are those which have surface imperfections, or which reach the cold straightening press with sharp kinks or too much camber. The ends of No. 2 rails are painted white and a punch mark is made on the side of the web near the heat number at one end. Usually No. 2 rails to the extent of 5 per cent. of the entire order will be accepted by the railway. The standard length is 33 ft. at a temperature of 60°F. Ten per cent. of the order is usually allowed to be in shorter lengths, varying by 1 ft. from 32 to 25 ft. A variation of ⅜ in. from the specified length is allowed in 15 per cent. of the order, while the variation in the remainder must not be over ¼ in. The ends of No. 1 rails less than 33 ft. long are painted green.

106. Tests.—Both chemical and physical tests usually are specified. For each heat, the manufacturer furnishes the inspector a chemical analysis of the elements carbon, manganese, silicon, and phosphorus, and also sulphur if specified. The physical qualities are determined by the drop test. A test-piece of rail from 4 to 6 ft. long is cut from the top end of the top rail of the ingot. This is marked on the base or head with gage marks 1 in. apart for 3 in. on each side of the center, for measuring the ductility of the metal. When cooled to a temperature between 100° and 80°F. the test-piece is placed, preferably base upward, on supports having a top radius of 5 in. These are spaced 3 ft., center to center, and are securely fastened to an anvil weighing at least 20,000 lb. and which is supported on springs. A tup or drop-hammer, which has a striking face with a 5-in. radius and weighs 2000 lb., is allowed to fall freely between guides and to strike the center of the test-piece. The height of fall is 16 ft. for 70-lb. rails, 17 ft. for 80-, 85- and 90-lb. rails, and 18 ft. for 100-lb. rails. Under these impacts the rail under one or more blows shall show at least 6 per cent. elongation for 1 in., or 5 per cent. for each of two successive inches of the 6-in. scale.

The allowable permanent set is slightly different for Bessemer than for open-hearth rails of the same weight. For a 100-lb. Bessemer and a 90-lb. open-hearth rail of the A. R. A.-A section, it is 1.65 in. in a length of 3 ft. At least one piece should be tested from each heat of Bessemer steel, and one from at least the second, middle and last full ingot of each open-hearth heat. Test-pieces which do not break under the first or subsequent blows are nicked and broken to determine whether the interior metal is sound. This test to destruction, often called the nick-and-break test, is the one in particular which many manufacturers have heretofore refused to make.

107. Shape and Weight of Section.—As the size of the rail section is increased, the strength of the rail is not increased in direct proportion, because of the less amount of work done on the larger than on the smaller section per unit volume of steel. The distribution of the metal between the head, web, and base affects the temperature at which the rails can be finished. The shape of each of these parts affects the ease of rolling and the amount of work done on each part or surface while being rolled. Sixty-three per cent. of all rails rolled in 1913 and 72 per cent. of all those rolled in 1914 were of 85-lb. section or heavier.

The magnitude of the fishing angles has an effect upon the performance of the rail-joint. The greater the angle the quicker the splice-bars will work loose as a result of wear on many surfaces and the loosening of the bolts. Also, a greater amount of stress is transmitted to the head and nut of the bolt. The fishing angles should be made as small as consistent with good rolling. The fishing angles of the head and base are usually the same but in the P.S. section the fishing angles are 15° for the head and 13° for the base. The wedging action of the splice-bar between the head and base of the rail as the bolts are tightened is greater for small fishing angles.

108. Special Sections.—Several special and compound rail sections have appeared from time to time. The compound sections have a detachable head which can be removed and replaced by a new head or wearing surface when the old one becomes worn. Some years ago the Baltimore and Ohio R. R. tried the Manning rail, which had an eccentric head $\frac{1}{32}$ in. wider on the inner side and $\frac{1}{32}$ in. narrower on the outer side than the standard head. The Lehigh Valley R. R. is now using a special 110-lb. rail on steep grades and sharp curves. This has a larger and deeper head and heavier web than the standard 100-lb. rail. The section of this rail is shown in Fig. 47. The Pennsylvania Railroad has laid a small tonnage of 125-lb. rails, and since 1910 the Central Railroad of New Jersey has had in track a considerable tonnage of 135-lb. rails. In 1915, the 135-lb. rails had developed three to five times the life of 90-lb. rails and were still in service.

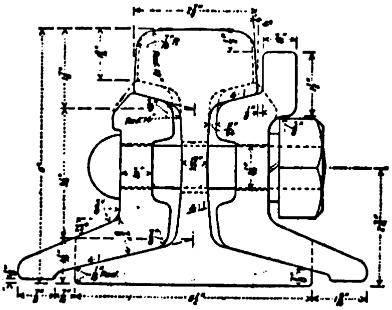


FIG. 47.—Special 110-lb. rail section for curves and grades, Lehigh Valley R. R.

A rail known as the "frictionless" is being used by the Southern Pacific Co. on many 9° and 10° curves. The rail has a narrow and deep head. The height of the rail is $6\frac{3}{32}$ in., width of base $5\frac{1}{8}$ in., width of top of head $1\frac{3}{4}$ in., and depth of head $1\frac{15}{16}$ in. A rail of the same type, used since 1914 on some curves of the Delaware, Lackawanna & Western R. R., is shown in Fig. 66. A similar rail is being tried on several other railways.

The Pennsylvania Railroad has recently designed a 120-lb. rail having a flare of 8° to the sides. This is a tendency to revert to the Sayre rail of 1883 which had a flare of 10°. Since that time, if the sides of the head were not vertical, the flare was limited to 3° or 5°. The New York Central has had a standard 105-lb. section of the Dudley type since about 1910 (Fig. 60). The Delaware, Lackawanna & Western R. R. also has a rail section of the same weight.

109. Length.—Since the earliest days of railroading, rail-joints have been a source of much trouble. The standard length of T rails on American railways is 33 ft., though many 30-ft. rails are still used. The use of longer rails would reduce the number of joints and correspondingly reduce joint-troubles. Also, with fewer joints more money could be spent on strengthening the remaining joints. Long rails are now the standard on street-railways using girder rails. In adopting a standard length several things must be considered: (1) whether a longer rail would require a change in present mill-practice and mill equipment; (2) the transportation of longer rails; (3) the most suitable length of rail to give the best track at a minimum cost for material and maintenance labor.

The existing equipment at a few mills would require no change to manufacture long rails. Most mills would have to make some changes in equipment. Several rail manufacturers claim that it is not possible to give as good a surface finish to long rails as to short rails. With the present car equipment of most railways, rails over 40 ft. long would have to be handled in two open-top cars. Practically all railways could transport 36-ft. rails.

The ultimate factor limiting the length of rail is the maximum expansion-joint that can safely be used. Forty-five- and 60-ft. T rails have been tried in this country. From the general practice in Europe it appears that a length up to 45 ft. would be economical, provided the quality of the rail was not detrimentally affected and the cost of manufacture was not increased. Forty-five-foot rails tried on the New York Central R. R. were unsatisfactory because they proved to be of an inferior quality. Rails of this length are now in use in the Hoosac tunnel on the Boston and Maine R. R. Between 1902 and 1905 the Norfolk & Western Ry. bought a large number of 60-ft. rails with mitered ends. The mitered ends were not satisfactory. The company stopped buying the 60-ft. rails because they cost more per ton than shorter rails. In England a few 30-ft. rails, a very few 60-ft. and a large number of 45-ft. rails are used. The 45-ft. length is now considered as standard. In France and Belgium the length is from 54 ft. 2 in. to 78 ft. 9 in., the commonest being 59 ft. In Germany the usual lengths are from 29 ft. 6 in. to 49 ft. 3 in., while 59-ft. rails are used considerably in tunnels and on bridges. In Austria and Hungary the lengths range from 41 ft. to 49 ft. 3 in.

110. Expansion.—When rails are being laid, an allowance is made for expansion by keeping the ends of adjacent rails separated by a narrow space. The width of the space depends upon the average temperature of the rail at the time it is being laid. The average temperature is found by means of a track-thermometer laid on the head of the rail and left in position long enough to correctly register the temperature, the thermometer being shaded from the direct rays of the sun. Table 12 gives the standard expansion spacing for 30- and 33-ft. rails for all temperatures.

TABLE 12.—EXPANSION SPACING FOR LAYING 30- AND 33-FT. RAILS

Temperature (Fahrenheit)	Width of expansion space
Minus 20° to 0°	$\frac{5}{16}$ in.
0° to 25°	$\frac{1}{4}$ in.
25° to 50°	$\frac{3}{16}$ in.
50° to 75°	$\frac{1}{8}$ in.
75° to 100°	$\frac{1}{16}$ in.

Over 100° rails should be laid close without bumping.

The Pennsylvania Railroad uses the same expansion spacing as given in the table, but with temperature ranges of $-10°$ to 14°, 14° to 38°, 38° to 62°, 62° to 86°, and 86° to 110°. A few roads in the South use the same temperature interval and expansion spacing for a range of 0° to 120°. In tunnels, rails are laid with close joints for a temperature above 70° and an opening of $\frac{1}{16}$ in. is provided for each 20° or 25° below 70°. In very hot weather, if the track shows a tendency to buckle, it may be necessary to drive back the rails or to cut a piece out of the rail. At insulated joints at the ends of track circuits a spacing of about $\frac{1}{2}$ in. is necessary. Insufficient expansion spacing on steep grades increases the creeping of the rails.

111. Rail Failures.—Practically all rail failures are the result of defects in the rail due to faulty manufacture. These defects are not noticeable in the newly laid rail, but under the action of traffic they are gradually accentuated until failure occurs or the defects become noticeable.

During the past few years failures have received much study and investigation in an endeavor to ascertain their primary causes. The American Railway Engineering Association has prepared seventeen standard blank forms for recording the life history of a rail from the time the ingot is cast, through the period of manufacture, tests, inspection, shipment and service in track, until the rail is finally removed from track because of natural wear or premature failure.

A rail is removed from the track for one of the following reasons:

1. Flow of metal of the head.
2. Split web.
3. Crushed head.
4. Split head.
5. Transverse fissure (oval spots in rail-head).
6. Broken rail (square and angular breaks).
7. Broken base (crescent breaks).
8. Damaged rail.
9. To be replaced with heavier rail.
10. Normal wear.

Steel contains impurities such as carbides, phosphides, silicides, etc., each of which solidifies at a different temperature, but all of which solidify at a lower temperature than metallic iron. Hence, those having the lowest solidifying point will tend to gradually segregate from the iron and concentrate in the hottest part of the ingot, which is the center and top. Consequently the center and top of the ingot always contain the largest amount of impurities. Improper mixing of the molten metal is another cause of segregation. Segregation is usually accompanied by interior sponginess and external softness of the metal and can be avoided only by using thoroughly mixed, well-deoxidized, and quiet-setting steel. The etched section of the head of a rail showing segregation is shown in Fig. 48.[1] This indicates too little cropping of the ingot.

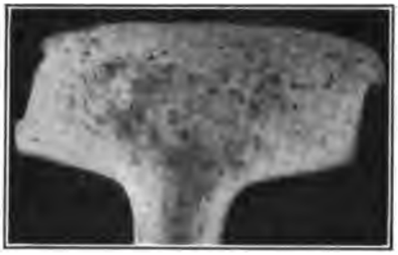
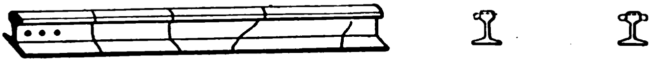


FIG. 48.—Rail showing segregation and otherwise unsound steel—too little cropping of the ingot.

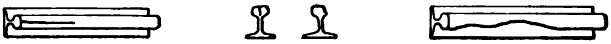
Flow of metal is the name given to those failures which show a flowing or rolling out of the metal of the head toward the sides, without a breaking down of the head structure, that is, the under side of head is not distorted (Fig. 49*b*). It is not a dangerous type of failure and is most prevalent at the ends of the rail. It is caused by the metal in the top of the rail-head being stressed beyond its elastic limit. Slipping wheels and loose joints are largely responsible for this type



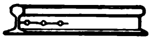
(a.) Broken Rail.

(b.) Flow of Metal.

(c.) Crushed Head.



(d.) Split Head.



(e.) Split Web.

(f.) Broken Base.

FIG. 49.—Types of rail failures (Am. Ry. Eng. Assn.).

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[1] Figures 48 and 50 to 54 are reproduced by the courtesy of Mr. Robert Job, Vice-President, Milton Hersey Co., Montreal, Canada.

of failure. Flowing of the metal has occurred on the right-hand side of the rail in Fig. 48.

Split-web failures are those rails which show longitudinal splits along the axis of the web, usually starting from the bolt-holes at the end of the rail (Fig. 49*e*). Loose joints and segregated metal are usually the cause.

Crushed-head failures include all rails that show a breaking down of the head structure. This form of failure is easily detected in track by the widening of the rail-head, the appearance of a dark streak in the center of the top of the head, indicating that a portion of the metal is depressed and is not receiving the usual polishing from the wheels, or by a distortion of the fishing angle (Fig. 49*c*). This defect develops slowly and is found both in segregated and in unsegregated steel. It is sometimes caused by pipes but more frequently is the result of segregation. Figures 50 and 51 illustrate this type of failure.

Split-head failures include rails split through or near the center line of the head, or rails with pieces split off the side of the head (Fig. 49*d*). The cracks are usually vertical. Figure 52 shows a longitudinal fissure in the head, a rather unusual failure of this kind. The causes of split heads are the same as those of crushed heads.

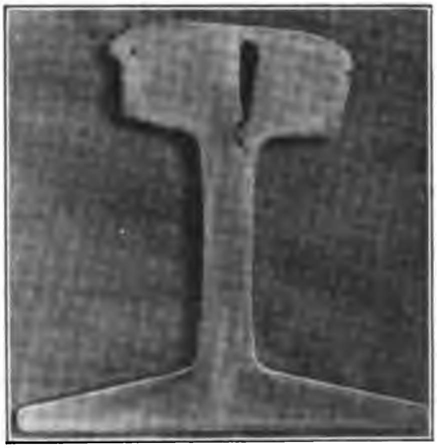

Fig. 50.—Crushed head—unsound steel.

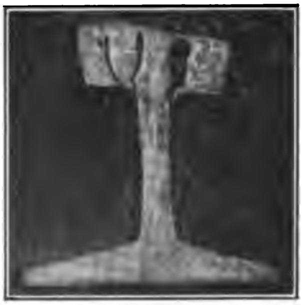

Fig. 51.—Badly crushed and split head—unsound steel.

Transverse or internal fissures have been recognized only recently in this country. Their cause is not fully known but appears to be due to segregation and to the presence of numerous minute cracks in the interior of the rail-head. These cracks appear to be produced by some condition of rolling. The stresses in the rail cause these small cracks to grow until failure occurs. Figure 53 shows a rail which failed from transverse fissure, a characteristic silvery oval spot being visible.

A broken rail is one which is broken through, being separated into two or more parts, or a rail showing a crack which might ultimately result in a complete break (Fig. 49*a*). Failures of this kind are the most dangerous, since it is the rail which suddenly fails that is to be feared. The majority of broken rails have their origin in seams in the bottom of the base. Seams may be caused by breaks in the skin of the ingot during the early passes through the rolls; or they may be rolled out pipes, blow-holes, or surface pits of the ingot. Contributory causes of this kind of failure are metal which is hard but low in ductility; segregation; internal strains in the head caused by rapid cooling of the metal; and the removal of kinks in the cold-straightening press. A badly piped rail is shown in Fig. 54. This is the result of too little cropping.

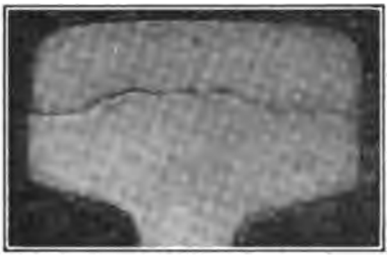

FIG. 52.—Longitudinal fissure in head—unsound steel.

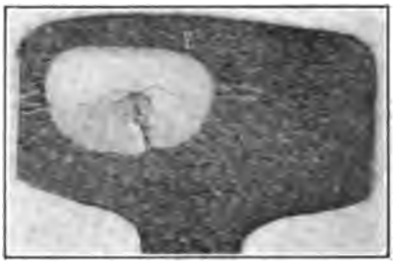

FIG. 53.—Transverse fissure—silvery oval spot in head.

Broken-base failures include all breaks in the rail-base (Fig. 49*f*). These usually take the form of a crescent-shaped piece breaking out of the flange over a tie. The direct cause is unequal loading of the flange, as on curves, or an uneven bearing of the base on the tie. Seams in the bottom of the base are the indirect cause.

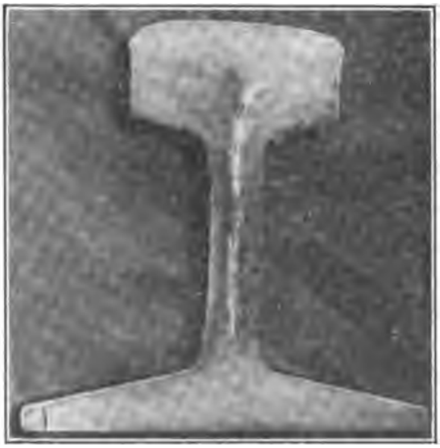

FIG. 54.—Badly piped rail—too little cropping of the ingot.

All rails broken or injured by wrecks, defective wheels, or by other than normal traffic conditions are classed as damaged.

When an increase in weight of equipment or volume of traffic makes it necessary to lay heavier rails, all sound rails of the lighter section can be relaid in track carrying lighter traffic, while those badly worn or defective can be used in sidings and yard-tracks.

The wear of rails is discussed in Art. 113. Normal traffic may cause a rail to be removed because of wear in one of three ways: (*a*) loss of metal from the top of the head; (*b*) loss of metal from the side of the head; (*c*) rails bent down at the ends as a result of weak, loose, or low joints. Bent ends are classed by some persons as damaged rails, but it appears better to include as damaged rails only those damaged by abnormal traffic conditions. Bent ends are the result of normal traffic, though abnormal track conditions.

Up to October, 1913, the failure of rails rolled in the years 1908 to 1911 inclusive, showed a steady increase in the proportion of failures in Bessemer rails. Between 1911 and 1913 the failures of Bessemer rails per 10,000 tons rolled were over two and one-half times those of open-hearth rails.[1] During the first year after new rails are laid there are comparatively few failures. Most failures occur after the first year and before the sixth year of service in the track. There is a great difference in the number of failures of rails of the same weight and section made by different manufacturers. This indicates faulty mill-practice at certain mills. The percentages of the different kinds of failures to total failures for the 6-year period 1908 to 1913 were as follows:[1] (1) For Bessemer rails, head, 39 per cent.; web, 4 per cent.; base, 19 per cent.; broken, 38 per cent. (2) For open-hearth rails, head, 47 per cent.; web, 9 per cent.; base, 9 per cent.; broken, 35 per cent. The A. S. C. E. sections showed fewer head and web failures and more base and broken failures. The A. S. C. E., A. R. A.-A, and A. R. A.-B sections show about the same failure tendency. There are no data to indicate that the weight per yard has much influence upon the number of failures per 10,000 tons. In the past, the failures of "A" rails from the ingot have been about 2½ times as numerous as those of lower rails. From data collected by the Rail Committee of the American Railway Engineering Association it appears that, as a general average, about 1¼ per cent. of all rails laid are removed during the first 5 years because of failure. The failures of titanium-treated rails have been slightly less per 10,000 tons than the failures of carbon rails. The actual number of rail failures would be shown better by changing the basis of comparison from 10,000 tons rolled, to a certain number of rails in track, say, failures per 100 miles of track. The manufacturer should be required to replace all rails which fail during the first 5 years because of defective manufacture.

112. Classification for Track Purposes.—Each railway classifies rails according to the use made of them in the track. Second-class and short rails are not allowed in high-speed tracks but may be used in low-speed tracks, switch leads and yard-tracks. The Canadian Pacific Railway classifies rails as follows:

1. New rails—all rails not previously in service.
2. Main-line relay rails—all second-hand rails not less than 24 ft. long, provided the rails are sound throughout; if curved, can be straightened with a rail-bender when necessary, and which show a wear not in excess of the following: A vertical wear on top of head of ⅛ in. for 80- and 85-lb. rail and 3⁄16 in. for 100-lb. rail; a

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[1] Bulletin 170, American Railway Engineering Association.

wheel-flange wear of head of 1/16 of the original width; a wear under the head that will leave not less than 1/8 in. between the angle-bar and the web of the rail; ends bent down 1/16 in. in a length of 2 ft. or less.

3. Branch-line relay rails—any rails not less than 20 ft. long that are sound throughout, which, if curved, can be straightened with a rail-bender when necessary, and which show a wear not in excess of the following: A vertical wear on top of head of 3/8 in. for 100-lb. rail, 1/4 in. for 60- to 85-lb. rail and 1/8 in. for 56-lb. rail; a wheel-flange wear of head of one-eighth of the original width; a wear under the head that will leave not less than 1/16 in. between the angle-bar and web; ends bent down 3/16 in. in a length of 2 ft. or less.

4. Siding rails—all those unfit for main or branch lines, but which still have service left in them. These include rails with badly battered ends, rails with broken flanges that can be strengthened by using angle-bars, and piped rails. These must be not less than 15 ft. long.

5. Scrap rails—all those which are twisted or bent and cannot be straightened; pieces of all rails less than 6 ft. long; rails from which the following serviceable lengths cannot be cut: 80-, 85-, and 100-lb., 11 ft.; 72- and 75-lb., 14 ft.; 65-lb. or less, 6 ft.

6. Rail-rack rails—all rails distributed on rail-racks.

7. Auxiliary and emergency rails—all rails loaded on auxiliary cars for emergency purposes.

113. Life and Wear.—The life of rails of the same weight and section and under the same traffic varies considerably because of different qualities of the metal. Besides the chemical composition and method of manufacture, the wear of a rail depends upon whether the rail is placed on a tangent or a curve, on the outer or inner side of a curve, or on a steep grade. Even when a rail is so worn that it is no longer fit for service, the actual proportion of metal lost by wear is comparatively small. Sound worn rails can be heated in a reverberatory furnace and rerolled into new rails having a lighter section than the old rails. The tonnage of rerolled rails has slowly increased. In 1913, 4.4 per cent. and in 1914, 4.8 per cent. of the total tonnage rolled was rerolled from old rails. The life of a rail in years is governed by the allowable percentage of wear and the tonnage of traffic passing over it. The normal life of a rail limited by wear is from 1 to 20 years. The only reasonable basis of comparison is by the number of tons of traffic passing over the rail and the position of the rail in the track. Figure 55 shows an 85-lb. P. S. section Bessemer rail after 16 years of service in track on the Pennsylvania Railroad. The rail was on the high side of a 2° curve and on a grade of 0.87 per cent. The best record available is that of the 6-in. 100-lb. Dudley sections laid in 1895 on the New York Central & Hudson River R. R., which, until August, 1907, had carried 375,000,000 tons with a loss of about 1/8 in. in depth of the head.

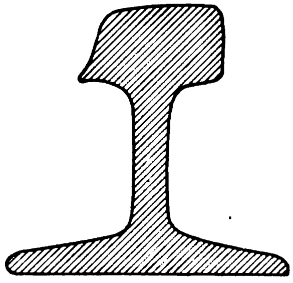

FIG. 55.—Rail in track 16 years on high side of 2° curve.

Rails are usually removed from the main track when so worn that the following conditions exist: when the splice-bars are being cut or struck by the wheel-flanges; when the side of the head is worn as much as one-eighth the original width or when the side of the rail-head is worn to the shape of the wheel-flange and fillet so that the wheels are liable to mount the rail; when the top of the head is worn ¼ in. The percentage of the area of the cross-section which can be worn away to produce the above conditions depends upon the type and weight of rail. Rails on tangents and on the inside of curves wear mostly on the top of the head. Rails on the outside of curves wear mostly on the side of the head. In any case, irrespective of where the greatest wear occurs, there is also some wear of the other kind. The maximum allowable reduction in area of head while in main track, due to wear of all kinds, is about 25 per cent. The area of the head of a 100-lb. A. R. A.-A section is 3.64 sq. in. The total area is 9.84 sq. in. A reduction of 25 per cent. in the area of the head would mean a loss of 0.91 sq. in., or 9.25 per cent. of the total sectional area. This is equivalent to a loss of 9.25 lb. of metal per yard.

In November, 1909, six rails of the 100-lb. A. R. A.-A section and six rails of the 100-lb. P. S. section were laid on a 7° 45′ curve on the Pennsylvania Lines West.[1] Three of each section were on the high side and three on the low side. These were removed in August, 1911, after 1 year and 9 months service, it being considered that the A. R. A.-A rails were too badly worn for further service. The average abrasion of the six rails of this section was 0.87 sq. in. The loss was at the rate of 0.36 sq. in. per 10,000,000 tons of traffic. The average loss of the six P. S. rails was 0.62 sq. in., at a rate of 0.27 sq. in. per 10,000,000 tons of traffic. The average loss of six A. S. C. E. rails, which were replaced by the test-rails after 2 years and 6 months service, was 0.53 sq. in., and the loss was computed to be at the rate of 0.22 sq. in. per 10,000,000 tons, though there is not the same accuracy in the traffic figures as for the test-rails. Abrasion of rails on tangents is at the rate of about 0.10 to 0.15 sq. in. per 10,000,000 tons of traffic. The use of sand, as on steep grades, about doubles the wear.

Rails with bent ends make a rough-riding track, increase the wear of the rolling-stock, and increase the tractive resistance. Several American and European railways have tried taking up the rails and cropping the damaged ends. This has been a common practice on the Northern Railway and Western Railway in France, but in this country the cost has exceeded the resulting benefit.

A peculiar condition of rail wear observed principally on street-railways, but occasionally on steam-railways, is the formation of transverse corrugations on the head. These make a noisy and rough-riding track and increased maintenance costs. Their cause is not exactly clear. One explanation is that in time they develop as the result of the vibration of the rail as it leaves the rolls in the mill. The corrugations occur from 1 to 1½ in. apart and are about 0.01 in. deep. They are removed by grinding away the top of the rail-head or by electrically welding steel into the depressions.

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[1] Bulletin 170, American Railway Engineering Association, page 319.

114. Girder Rails.—Girder rails are used most commonly on street-railways, but are used to some extent on steam-roads where the tracks are in paved streets. Practically all girder rails now being used are either grooved, side-bearing or high T rails. A flangeway can be provided for T rails by bolting a special Z-shaped guard on the inside of the rail-web. High T rails 7 and 8 in. deep have been used. Grooved and side-bearing girder rails up to a height of 9 in. are used. The heavy girder-rail track-construction of the Pennsylvania Railroad for steam-tracks in city streets is shown in Fig. 56.

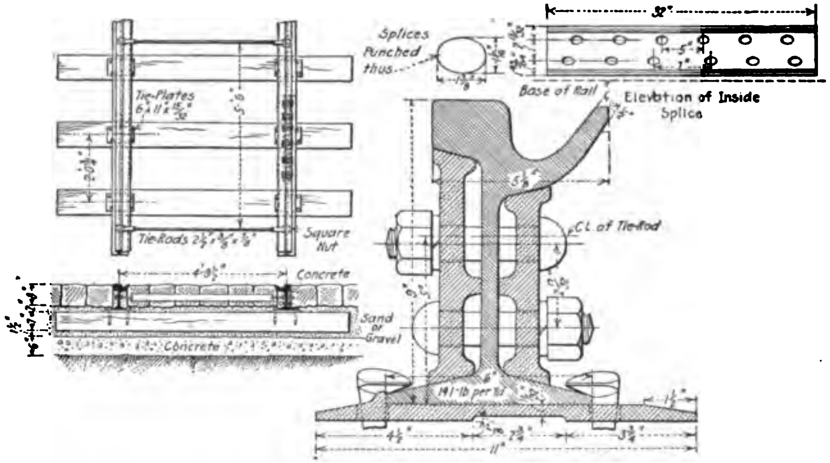


FIG. 56.—Girder rail for steam-railroad tracks in city streets; Pennsylvania Railroad.

CHAPTER IX

TRACK FASTENINGS

RAIL-JOINTS

115. Position of Rail-joints in the Track.—Rails may be laid with even (square) or broken joints, that is, with the joints of the two lines of rails opposite each other, or with the joint on one rail opposite the middle of the other rail. Even joints may be used on new lines not fully ballasted, in places where the roadbed is settling, and on earth-ballasted track. Practically all ballasted track is laid with broken joints (Fig. 57). Where the track has many low joints, as over a settling roadbed, there will be just half as many low spots in the track if the joints are even than if they are broken. Hence the track rides easier. With low joints on track having broken joints the wheels are thrown against the low rail, causing wobbling of the trucks, and the track eventually is thrown out of line. In ballasted track, broken joints hold surface and line better, distribute the hammer at the joints over a larger area of the track, and, in general, are easier maintained. The allowable distance that a joint may run ahead of the center of the opposite rail varies from 6 to 18 in. on different railways. The difference in length in feet of outer and inner rails for all curves can be found by dividing the central angle of the curve in degrees by twelve. Rail-joints should not be placed near the center of street or road crossings, on stock-guards, or on embankments within 8 or 10 ft. of the ends of bridges.

116. Rail Ends.—At one time it was thought that the damage to rails at the joints was due entirely to the blow delivered by the wheel to the receiving end of the rail as the wheel jumped the expansion space. This led to experiments with miter-joints or rails having the ends beveled, so that each rail directly carried part of the load at the joint. For about 25 years prior to 1895 the Lehigh Valley Railroad used the Sayre joint, in which the rails were cut at angles of 45° or 60°. Miter-joints were recently revived and tested on the Pennsylvania Railroad with unsatisfactory results. The experience of the Norfolk & Western Ry. was the same. The tendency is for rails not properly spaced for expansion or not properly anchored to push past each other and to be damaged by the wheel-flanges. In some cases derailments resulted by a wheel-flange mounting the projecting end. A joint known as lap or scarfed has been used in Europe. Half of each rail is cut away for a distance of 3 to 6 in. along a vertical plane through the center of the web. The two halved ends are lapped and bolted together.

117. Types of Joints.—The term "rail-joint" properly belongs to the ends of the rails. By common usage it has come to include all parts which connect the rails together. There are three types of joints used on American steam-roads: (*a*) suspended, (*b*) bridge, (*c*) supported. A fourth type, called base-joint, consists of a plate bolted to the bottom of the rails but not resting on the ties. This type has been used mostly on street-railways.

The two rail-ends of a suspended joint are placed between two ties called the shoulder-ties. This is spoken of as a two-tie joint. The shoulder-ties are spaced from 5 to 12 in. in the clear.

The rail ends in a supported joint rest on the same tie, called the joint-tie. A modification of the supported joint, called the three-tie joint, is used on several railways. With this joint two shoulder-ties are placed close to the joint-tie and the angle-bars are made long enough to extend over the three ties. The spacing of ties for the standard three-tie joint used on the New York Central and Hudson River Railroad for 36-in. splice-bars is shown in Fig. 57. It is claimed that the ties of a three-tie joint are too close together to permit of proper tamping and that either the joint-tie will be lightly tamped, making in reality a long span suspended joint, or that one or both of the shoulder-ties will be lightly tamped, making in reality a long span supported joint.

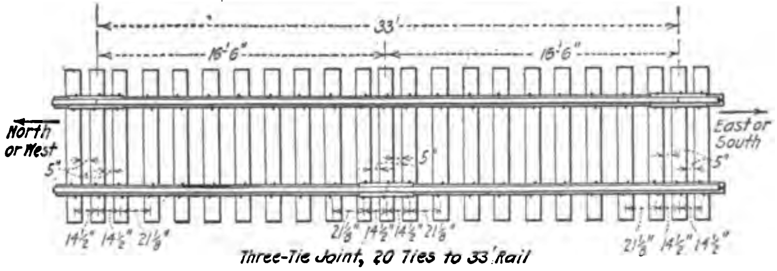


FIG. 57.—Spacing of ties for three-tie joint; N. Y. C. & H. R. R. R.

A bridge-joint is a suspended joint in which the base of rail is supported either by a flange of the splice-bar or by a separate base-plate. The supporting flange or plate has a bearing on and may or may not be fastened to each shoulder-tie. Many bridge-joints are in use in track carrying heavy traffic.

The majority of joints in America are of the suspended type. In England a few supported joints may be found in old track but with these exceptions the suspended joint is generally used. Some English railways use a special rail-chair on joint-ties, which has a longer bearing for the bull-head rail. In some cases the two chairs at the joint are connected by a plate which supports the rail, thus forming a bridge-joint. In France and Belgium the common joint is of the suspended type. Four-hole splice-bars of various designs are used. Some of these have a vertical web projecting below the rail to give additional stiffness to the joint. In Germany the joint-ties are spaced 13 to 15¾ in. center to center. In general, suspended 4-hole joints are used, many of the splice-bars projecting below the rail. A joint has been tried in which two ties are bolted together and placed under the joint. The top corners of the ties are beveled so that the rail-ends are unsupported for a few inches between the ties. Many bridge-joints consisting of a supporting plate are used. The plate often has a hooked rib on one side which fits over the rail-flange, while the other side is bolted to the flange. The plates are usually fastened to the shoulder-ties by screw-spikes. In Austria-Hungary long splice-bars with six holes have come into use but these have not proved entirely satisfactory and the tendency is to return to shorter splices with four bolts and to decrease the space between joint-ties.

118. Splice-joints.—The flat splice-bar or ordinary fish-plate was invented in America in 1830 by R. L. Stephens. In the early days the ends of the rails were not connected, the joints being placed on the supports. The first fish-plates were used for the purpose of preventing lateral movement only. As the wheel loads increased, the design of the fish-plate was changed so that it could assist in carrying the vertical load. The ideal joint would be one which had exactly the same rigidity and elasticity as intermediate parts of the rail. The string of rails would then act as a continuous girder having a variable moment of inertia, resting on multiple elastic supports. The wave motion of the rail would thus continue uninterrupted through the joint. Up to the present a joint giving exactly this condition has not been produced. The work which the splice-bars have to do is to hold together the ends, usually unsupported, of two independent rails and withstand the severe hammer from heavy drive-wheel loads at various speeds. The entire supporting power of the splice, except in the case of bridge-joints, is in the wedging action of the head and base of the splice against the head and base fishing surfaces of the rail. As long as a well-proportioned splice-bar is firmly clamped against these surfaces the joint performs its duties fairly well. But the action of traffic is to constantly loosen the joint, and its efficiency correspondingly decreases. While it is desirable that the splices be kept tightly clamped against the rail, they must not be clamped so tight that the rail cannot move longitudinally as it expands or contracts with changes in temperature. The frictional resistance of a tightly bolted joint of any of the commonly used splice-bars is from 30,000 to 65,000 lb., depending on the size of rail, length of bar, and number of bolts. It is apparent that this frictional resistance may cause a severe tensile stress in the rail due to a sudden drop in temperature; and a sudden rise in temperature may subject the spikes to a severe lateral or vertical pressure as the rail tends to bow at the middle. The wear and displacement of rail-joints is less with fast passenger-trains than with slow and heavy freight-trains. Besides, the wheels of the former are kept in better condition than are those of the latter.

119. Types of Joint- or Splice-bars.—The original fish-plate has been developed along several different lines. When greater strength was necessary than the original fish-plate gave, an upper and lower rib, or head and base, were introduced. This made a stiffer bar and increased the bearing surface against the head and base of the rail. This splice-bar is shown in Fig. 58. It is still frequently used on rails lighter than 50 lb. and in special cases on heavier rails. The stiffness of a fish-plate joint is from 10 to 20 per cent. of that of the rail. The angle-bar was the next development. An angle-bar joint is only 25 to 35 per cent. as stiff as the rail. Where greater strength is required a lower flange, projecting below the base of the rail, or an upper flange extending along the outer side of the rail-head, is added. A splice-bar of the upper flange type is shown in Fig. 47.

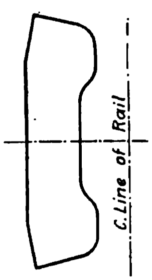


FIG. 58.—Improved type of fish-plate.

Splice-bars vary in length from 20 to 40 in., and have either four or six bolt-holes; a few bars up to 44 in. in length have been used. The four-hole 24- and 26-in. splices are in most common use. The usual length for a six-hole joint is 30 in. The bolts are spaced from 4 to 7 in. center to center. Differences in the practice of spacing bolts are shown in Figs. 59 to 75.

The angle-bar first designed by the American Society of Civil Engineers for use with the A. S. C. E. rail sections has been used more than any other form. For heavy wheel loads it does not give the rigidity that the ribbed bars give and its use is decreasing. This angle-bar is shown in Fig. 59. No part of the splice-bar of a supported joint can project below the base of rail. Hence the A. S. C. E. angle-bar or one of its several modifications is the type used for supported joints. The proportion of metal in the head and flange of some of the modifications of the A. S. C. E. angle-bar is increased, and in some the flange is carried down even with the bottom of the rail. Two of the latest developments of this bar are shown in Figs. 41 and 60. Figure 60 shows the Dudley type of angle splice-bar used by the New York Central and Hudson River Railroad for the 105-lb. rail. The angle-bar used with the 100-lb. P. S. rail on the Pennsylvania Lines West is shown in Fig. 41. These are the strongest angle-bars yet designed. The distribution of metal in these bars is such as to produce a bar about 30 per cent. stiffer than the bar shown in Fig. 59, while the weight of metal is but slightly greater. Practically all other splice-bars in use are patented and either have a bottom flange making a deep girder splice-bar which can be used only on suspended joints, or have a base support for the rail, making a bridge-joint. Deep flange and base-supporting splice-bars can be made about as stiff as the rail. These patented joints have given good results. In most cases the cost of maintaining them is from one-half to one-quarter that for angle-bars. The best-known splice-bars of the deep flange type are the Duquesne, the One Hundred Per Cent., and the Bonzano. The Duquesne joint is shown in Fig. 61. For 5½ in. at each end, the bar has a section similar to the A. S. C. E. splice-bar. Between the ties the bar has a lower flange projecting below the rail. This greatly increases the stiffness of the joint. The One Hundred Per Cent. joint is shown in Fig. 62. In general design it is similar to the Duquesne joint but the distribution of metal is such as to give a stiffer joint. The Bonzano splice-bar, shown in Fig. 63, has a head similar to the One Hundred Per Cent. splice-bar but has a vertical lower flange. The Superior joint, which combines the features of the bridge-joint and the deep flanged joint, is shown in Fig. 64. The splice-bar supports the rail for 7 in. at each end. The central 10 in. of this supporting plate is bent down to form a stiffening lower flange for the joint, leaving each rail-end unsupported for about 5 in.

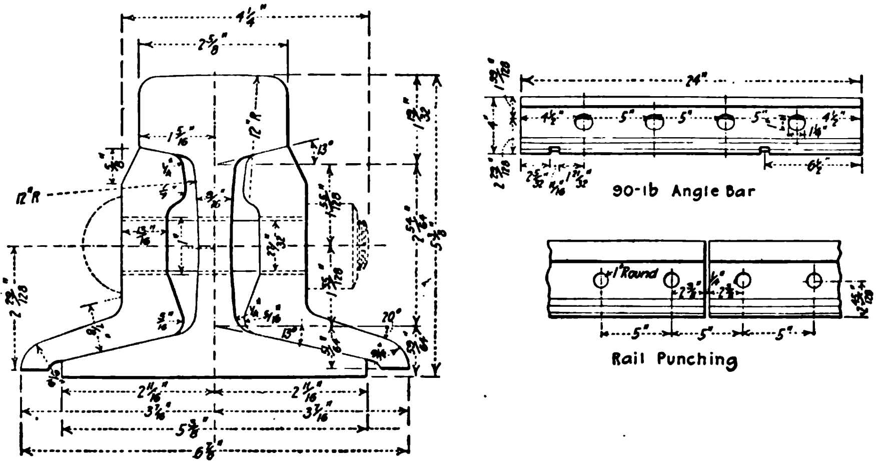


FIG. 59.—A. S. C. E. angle splice-bar for 90-lb. rail.

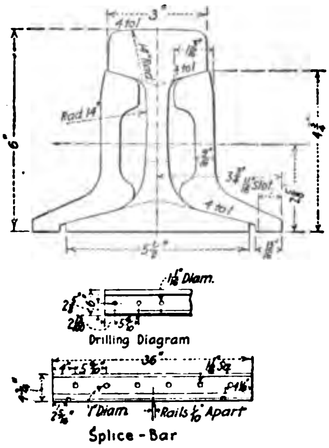


FIG. 60.—Dudley splice-bar for 105-lb. rail; N.Y.C. & H. R. R. R.

The best-known splice-bars of the rail-base supporting type, and the two most widely used of any patented joints, are the Continuous and the Weber. The Continuous joint, shown in Fig. 65, has the advantage of simplicity, there being only the two splice-bars. The lower flange of the splice-bar is bent inward to form a support for the rail the entire length of the joint. The flange, being unusually wide, permits the spike-holes to

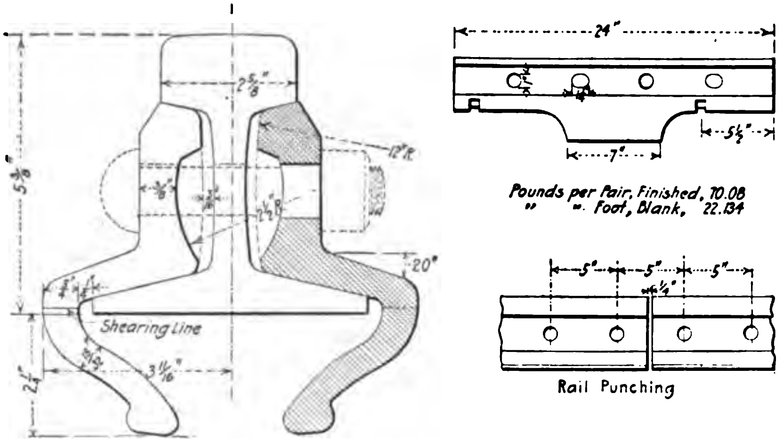


Fig. 61.—Duquesne splice-bar for 90-lb. A. S. C. E. rail.

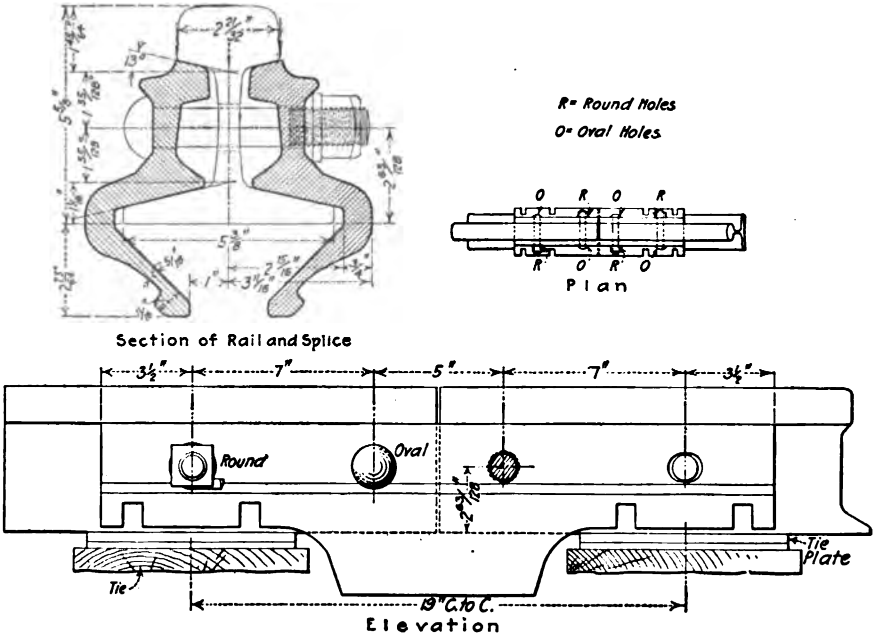


Fig. 62.—One Hundred Per Cent. joint for 100-lb. P. & R. rail.

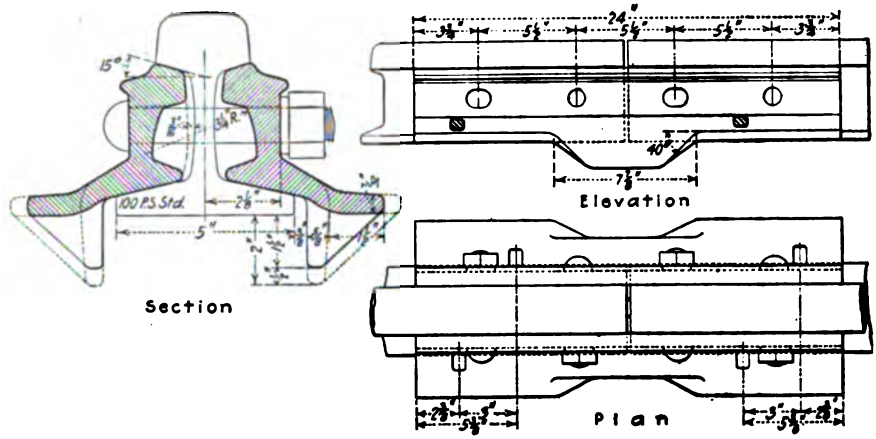


Fig. 63.—Bonzano joint for 100-lb. P. S. rail.

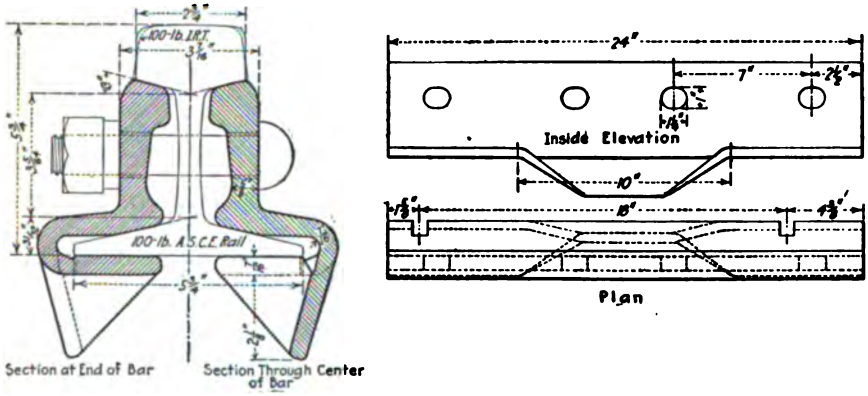


Fig. 64.—"Superior" joint.

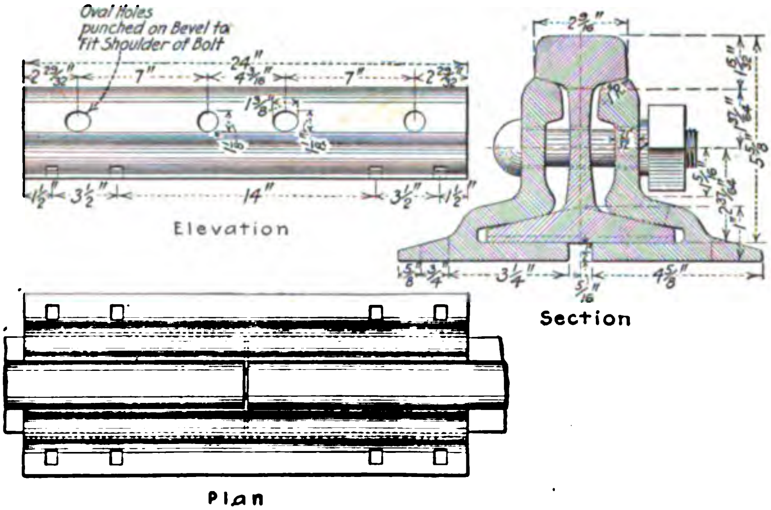


Fig. 65.—Continuous joint for 90-lb. A. R. A.-A rail.

be punched. When spiked through holes the joint is firmly held in place against creeping of the rails, which sometimes crowds the spikes out of slotted holes. The splice-bar is also made with a narrow flange. The Weber joint is made up of an ordinary angle-bar on one side, a channel splice-bar on the other side, a wooden filler in the channel, and a shoe-angle. The horizontal leg of the shoe-angle acts as a base-plate. The Weber joint used by the Delaware, Lackawanna & Western R. R. on the frictionless rail, and designed for screw-spikes, is shown in Fig. 66. For common spikes the base-plate is narrower and flat. A third joint of this type, the Wolhaupter, is shown in Fig. 67. It consists of a corrugated base-plate and two angle-bars, the lower flanges of which are bent in to grip the base-plate. The Abbott joint-plate, shown in Figs. 68 and 69, is designed for use with any angle-bar that does not project below the base of rail. By using this base-plate a bridge-joint is obtained. Four lugs, two at each end, engage the ends of the angle-bar and thus act as a rail-anchor. The plate is made with all lugs plain or with the two inner lugs hooked to fit over the rail-flange. With the first plates used the rail was held to the tie only by the hooked lugs. Later plates are made for a combination spiking in which the plate is fastened permanently to the tie with screw-spikes, while the rail is held with common spikes as in ordinary construction.

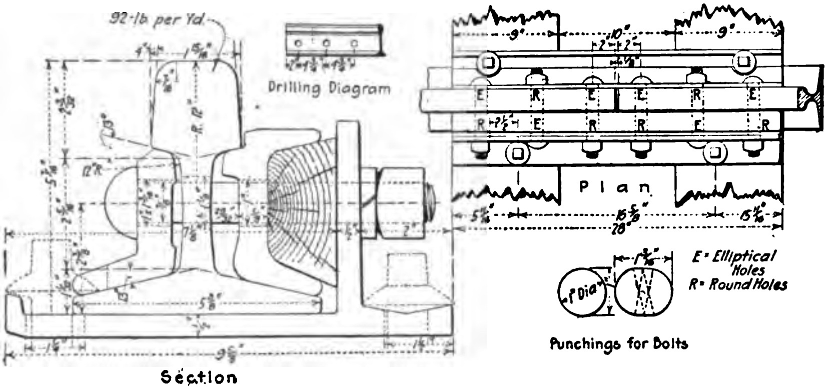


FIG. 66.—Weber joint on frictionless rail; D. L. & W. R. R.

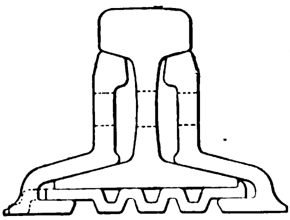


FIG. 67.—Wolhaupter joint.

Most splice-bars now in use are slotted for the spikes in a manner similar to that shown in the plan, Fig. 62. Several of those described above can be obtained with punched holes or without holes. Plain splice-bars are held by the head of the spike in the same manner that the rail is held. The spike-slots or -holes are for the purpose of preventing rail creeping but the plain splice-bar is gaining in favor among trackmen for the following two reasons: (1) The rail creeping can better be pre-

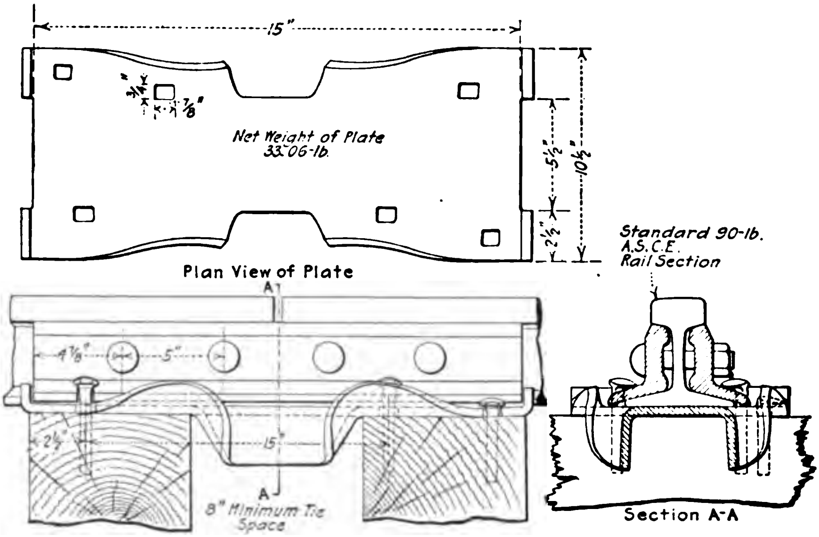


Fig. 68.—Abbott Rail Joint Plate.

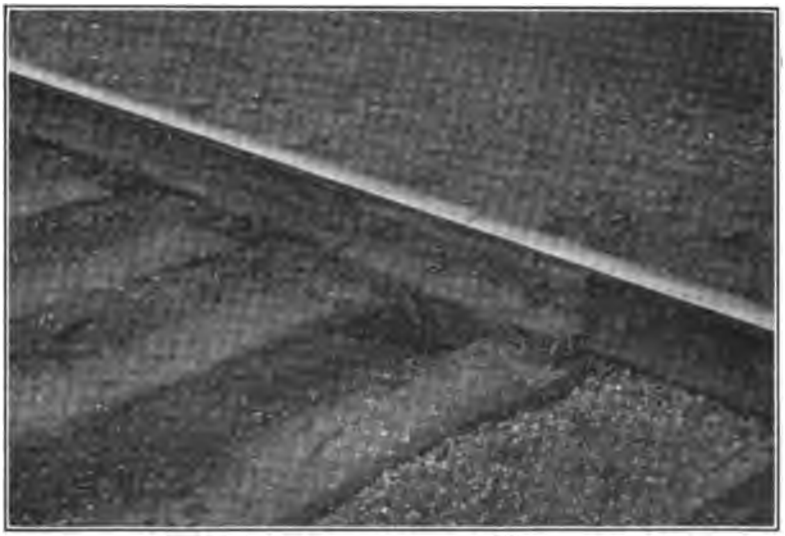


Fig. 69.—Track installed with Abbott Rail Joint Plates and hook-shoulder tie-plates.

vented by the use of special rail-anchors, as the splice-bar is called upon to perform enough functions without also acting as a rail-anchor. (2) In relaying rail the work can be done much quicker and cheaper, and the riding quality of the track will not be affected materially, if the joint-ties are not respaced and the rail-joints are allowed to fall where they may.

Bridge and angle splice-bars of the types previously described are made also to fit girder rails. The added depth of the splice-bar increases the stiffness of the joint so that bars with ribs projecting below the rail are unnecessary. Girder-rail splices of the reinforced fish-plate type are shown in Fig. 56.

120. Weight of Splice-bars.—The weight of the splice-bar depends upon the type of joint and the weight of rail. The number required per mile depends upon the average length of rail. The Duquesne splice-bars for 90-lb. A. S. C. E. rails, shown in Fig. 61, weigh 70.08 lb. per pair, finished. The Bonzano joint as applied to 100-lb. P. S. rails, Fig. 63, weighs 79.44 lb. per joint for 1½-in. lower flanges, and 86.4 lb. for 2-in. lower flanges. A 26-in. Continuous splice-bar applied to 90-lb. A. R. A.-A rails, Fig. 75, weighs 40.49 lb. The complete insulated joint weighs 93.85 lb. The 27-in. Continuous splice-bar for the same rail weighs 43.215 lb. In estimating the number of joints per mile of track an average rail length of 32 ft. is used. This allows for 10 per cent. of short rails and a few additional bars for turnouts. On this basis 660 splice-bars are required per mile of single track. This would require 14.261 net tons per mile of track for the 27-in. Continuous bar just referred to.

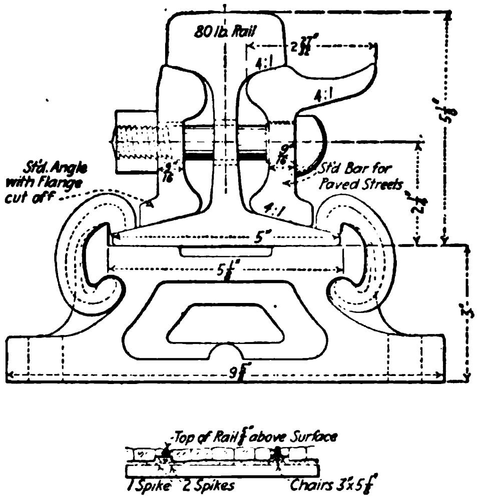

80 lb. Rail
4:1
4:1
4:1
Std. Angle with Flange cut off
Std. Bar for Paved Streets
5"
9
Top of Rail above Surface
1 Spike
2 Spikes
Chairs

FIG. 70.—Special splice-bar and Duggan rail-chair for use in paved streets; N. Y. C. & H. R. R. R.

121. Special Types of Splices and Joints.—The Musgrove joint is a combination tie-plate, rail-brace, and splice-bar. It is used only as a supported joint. A plate 17 in. long extends under the rail at the tie. On one side the plate bends up to form a rib which hooks over the rail-flange and acts as a rail-brace. This is elongated to form the splice-bar on one side and an ordinary splice-bar is used on the other side. A special splice-bar used on the New York Central and Hudson River Railroad to provide a flangeway in paved streets is shown in Fig. 70. An intermediate bar of the same section is bolted to the rail between joints. Several boltless joints have been proposed. These depend on some wedge or interlocking feature of the parts to hold the joint in place.

A boltless wedge type of joint, consisting of a cast-steel trough with hook flanges and two wedges, has been used with double-head rails. The trough is slipped over the base of the rail, and the wedges, one on each side of the rail, are simultaneously driven in opposite directions. A pin inserted in the small end of the wedge holds it in place. The Great Northern Railway of Ireland places a tie longitudinally under each rail, the two ties being connected by tie-rods. The Melaun joint has the head of each rail cut away for a few inches on each side of the joint. The gap is filled with a hollow saddle resting on the webs and flanges of the rails, and is bolted to a base-plate. In the Newmann joint a rib on the upper part of the outer splice-bar extends up to the top of the rails and carries the wheels for most of the length of the joint. The two joints last mentioned have been used in Germany.

122. Step-joints.—When rails of different sections come together a step- or compromise-joint is necessary. The splice-bars are of special rolled or cast section, half of which fits one rail section and half the other. The gage of the two rails must be kept continuous. Hence, on the outside, one rail-head will project beyond the other, so that the splice-bars must be made right-hand and left-hand. The extreme case of a step-joint is where a T rail and girder rail join. A rolled-steel step-joint of the Bonzano type is shown in Fig. 71.

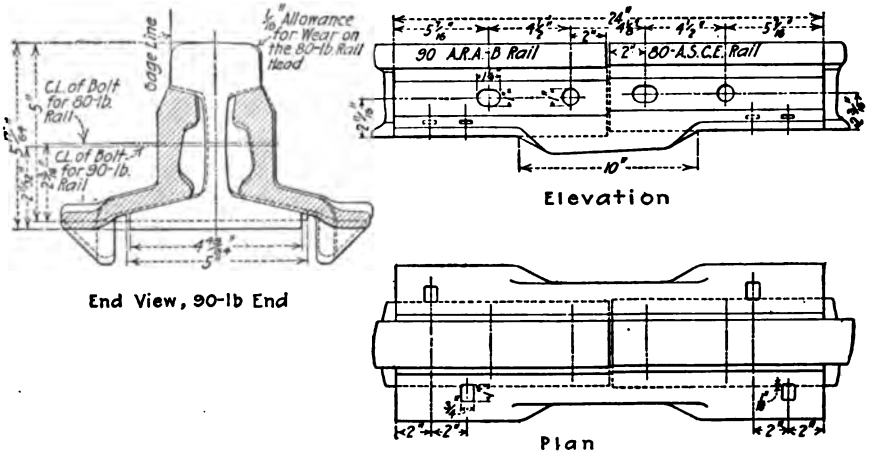


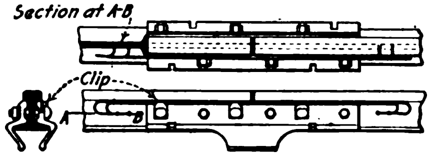
Fig. 71.—Bonzano step-joint.

123. Metal in Splice-bars.—For many years the metal in splice-bars was of a poor quality. The New York Central and Hudson River R. R. was one of the first railways which endeavored to get as good a quality of steel in the splice-bars as in the rails. The complicated section of many of the bars makes it difficult to roll them of high-carbon steel, which must be rolled hot with the result that deformation of the section may take place while cooling. Many splice-bars have been rolled from scrap steel. This is largely responsible for the lack of uniformity of different types of joints in service. The 1913 specifications of the Canadian Government Railways require angle-bars to have an ultimate tensile strength of 85,000 to 115,000 lb. per square inch and to have the following chemical composition: carbon, 0.52 to 0.66 per cent., average not less than 0.60 per cent.; manganese not to exceed 0.70 per cent.; silicon not to exceed 0.18 per cent.; phosphorus not to exceed 0.04 per cent.; sulphur not to exceed 0.05 per cent.

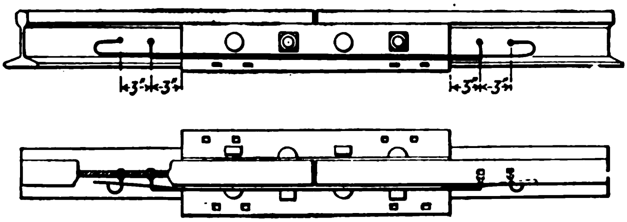
124. Welded Joints.—Welded joints are common on street-railways but have been tried on steam-roads only to a small extent and with unsatisfactory results. It is generally considered that if welded joints are not embedded in a pavement, excessive stresses will develop in the rail at high temperatures and will result in deformation of the track. Welded joints can be used on tracks in paved streets because (1) only the head of the rail is exposed to the outside temperature, while the body of the rail is kept at a more or less uniform temperature; (2) when a change of temperature does occur, the change takes place gradually; and (3) the confinement of the rail by the pavement prevents lateral and vertical deformation.

From a maintenance standpoint welded joints are undesirable for open track because a broken joint or broken rail would necessitate doing one of the following: rewelding the joint while in the track; removing the entire welded section; or cutting out a piece at the break and welding in a short piece of rail. Any of these would be expensive and might seriously interrupt traffic. Welded lap-joints have been tried on the Mecklenburg State Railway.

125. Bonded Joints.—Where electric track circuits are used for signal purposes it is necessary for each line of rails of the track to act as an electric conductor, equal in length to that of the block. In a new track, the splice-bars and bolts which fasten two rails together may furnish a continuous path from rail to rail for the electric current. But after being in service a while the joint cannot be depended upon to do this, and it is necessary to provide the electrical bond by connecting the ends of contiguous rails by one or two bond-wires 2 to 4 ft. long. Each end of the wire is connected to one of the rails. Two bond-wires ordinarily are used. The connection may be made to the top of the rail-flange or to the web. Web connections are by far the more common. The connection to the web is by means of a channel pin, which is a truncated cone with a longitudinal slot of radius equal to that of the bond-wire. The connection is made by inserting the pin and wire in a hole drilled in the rail and driving the pin in tight, thereby wedging the wire in place. The channel pin may be driven in a hole drilled in the web or in a hole drilled in a soft steel ¾-in. rivet pressed into the rail at the steel-mill. The bond-wire should be galvanized iron with a gage equivalent to No. 8 B.W.S. Copper or copper-clad steel wire of a gage equivalent to No. 6 B. & S. should be used through stations, road crossings and tunnels. Four bond-wires are sometimes used at such places. The bond-wires may be placed on either side of the rail but usually are on the inside. In some cases they are placed inside the splice-bars, that is, between the splice-bars and the rail-web. Some railways use bond-wire protectors (Fig. 72*A*), consisting of clips on the bolts, to hold the wires in place close to the rail. Figure 72 shows two kinds of bonded joints.

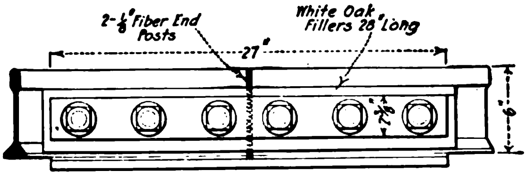


(A) Bond Wires and Clip; P.R.R.

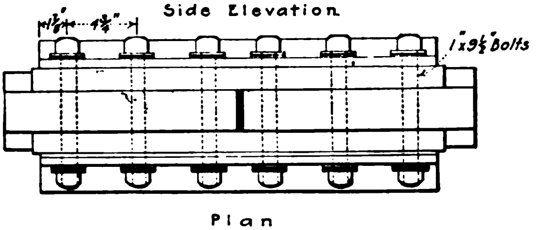


(B) Illinois Central

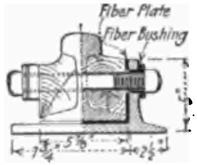
FIG. 72.—Bonded joints.



Side Elevation



Plan



Half Elevation and Half Section

FIG. 73.—Insulated Weber joint for 105-lb. rail; D. L. & W. R. R.

126. Insulated Joints.—Rail-joints at the ends of track signal circuit sections must be insulated in such a manner that no electric current can directly or indirectly pass through the joint from one rail to the other.

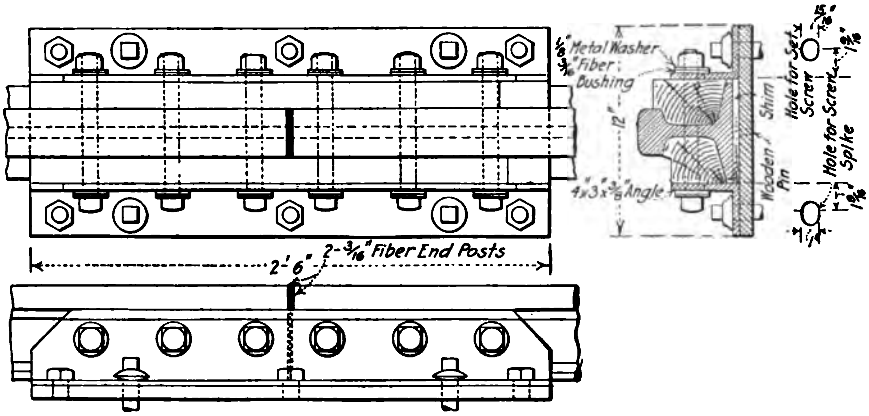

$\frac{1}{8}$" Metal Washer
$\frac{3}{16}$" Fiber Bushing
12"
4"x3"x$\frac{3}{8}$" Angle
Shim
Wooden Pin
Hole for Set Screw
Hole for Screw Spike
$\frac{15}{16}$"
$1\frac{9}{16}$"
$1\frac{9}{16}$"
2'-6"
2-$\frac{3}{16}$" Fiber End Posts

FIG. 74.—Improved Neafie insulated joint; D. L. & W. R. R.

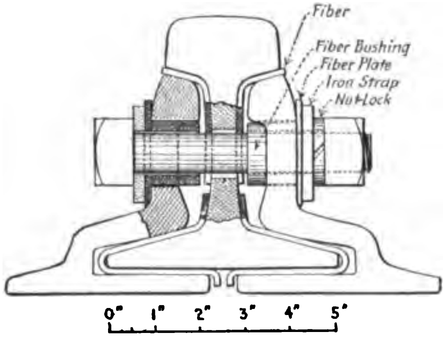


FIG. 75.—Insulated Continuous joint.

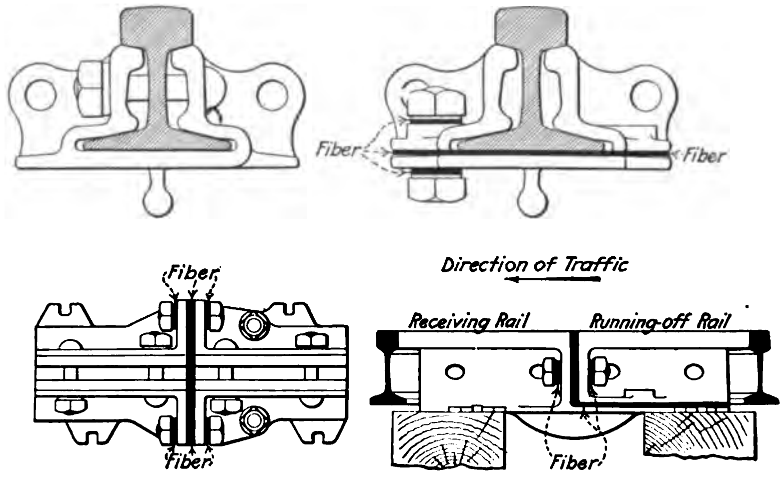


FIG. 76.—Trasco insulated joint.

This is accomplished by placing fiber plates between all contacts of the rail and the splice-bars, and placing fiber bushings and washers on the bolts. The insulation must be renewed at intervals of 2 to 4 years, hence to be successful the joint should be of simple design and the number of parts should be a minimum. In some designs only half of the joint is insulated. The insulated Weber joint, shown in Fig. 73, has been used extensively and has been satisfactory. The O'Brien joint is practically the same as the improved Neafie joint of the Delaware, Lackawanna & Western R. R., shown in Fig. 74. The insulated Continuous joint is shown in Fig. 75. The Trasco joint, shown in Fig. 76, is of an entirely different design from any of the others shown, as it is made in two parts longitudinally. The Keystone insulated joint is shown in Fig. 77. All parts, except the insulation, are metal. Two ways in which the ordinary angle-bar joint can be insulated are shown in Fig. 78.

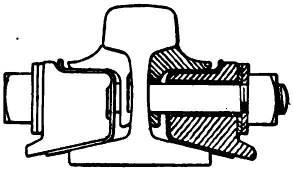


Fig. 77.—Keystone insulated joint.

127. Rail-joints at the Ends of Steel Bridges.—The expansion of long steel bridges makes it necessary to provide a special expansion-joint in the rails at the ends of the bridge and at intermediate points on long bridges. The expansion-joints for trusses of ordinary length must allow a movement of from 0.3 to 0.5 ft. The movement on some long cantilever bridges is from 1 to 3 ft. The rails at the ends of movable bridges must be locked in position by some form of wedge or plunger lock when the bridge is closed, and must be disconnected from the shore rails before the bridge is opened. The usual joint consists of two unspiked lift rails, each about 15 ft. long, firmly anchored and hinged at one end on the bridge. The free ends of the rails are planed on one side to a point and extend about 2 ft. beyond the end of the bridge to engage the similarly planed ends of the shore rails. The lifting rails are connected by struts. When it is desired to open a draw-bridge the rail-ends are unlocked, the bridge is unlocked, the lifting rails are raised far enough for them to clear the points of the shore rails, and the bridge is opened. A few joints have been used in which the ends of the rails are cut square and kept far enough apart

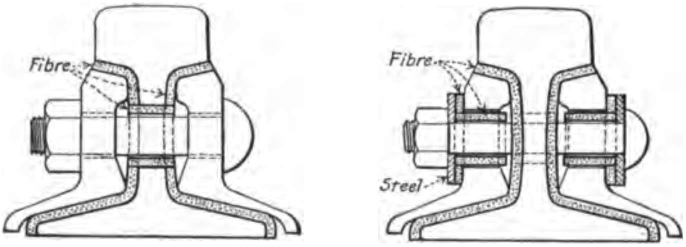


Fig. 78.—Two ways of insulating angle-bar joints.

to allow for the maximum expansion; the wheels are carried over the gap by sliding sleeves or joint-bars, operated from the power house on the bridge, or by easer rails placed against the outside of each rail, the wheels being held in position by guard-rails. A similar joint may be used solely for expansion on the structure. Some expansion-joints consist of switch rails which slide against each other. Others have a scarfed joint in which half of each rail is cut away and the planed surfaces slide on each other.

128. Track-bolts and Nuts.—Track-bolts are ¾, ⅞ or 1 in. in diameter, depending upon the weight of rail. The length of the bolt depends upon the particular type of joint and weight of rail, and varies from 3½ to 6 in. under the head. Longer bolts are necessary for insulated joints. The insulated joints shown in Figs. 73 and 74 require bolts 8½ in. long under the head. The threads either may be cut or cold-rolled. Most bolts have the threads cut out of the body, but some have the threaded part formed to a greater diameter than the body so that the threads do not weaken the bolt by reducing the cross-section. The threads used are the U. S. Standard (Fig. 79*B* and *C*) or the Harvey grip thread (Fig. 79*A*, *E*, *F* and *G*). The number of threads per inch varies from 11 to 8 and the length of threaded end is usually from 1¼ to 2 in., though the Grand Trunk Ry. specifies 2¼ in. for 90- and 100-lb. rail. For rail sections above 90 lb. the bolts are usually 4½ to 6 in. long under the head, have 8 threads per inch, and a threaded length of 2 in. The threads on the bolt and nut should be made to permit the nut to be screwed on with the fingers about ⅜ in. before the nut becomes "wrench tight," and then to be screwed up with an ordinary track-wrench without overstraining the threads or bursting the nut. Bolts are made with round or oval rivet

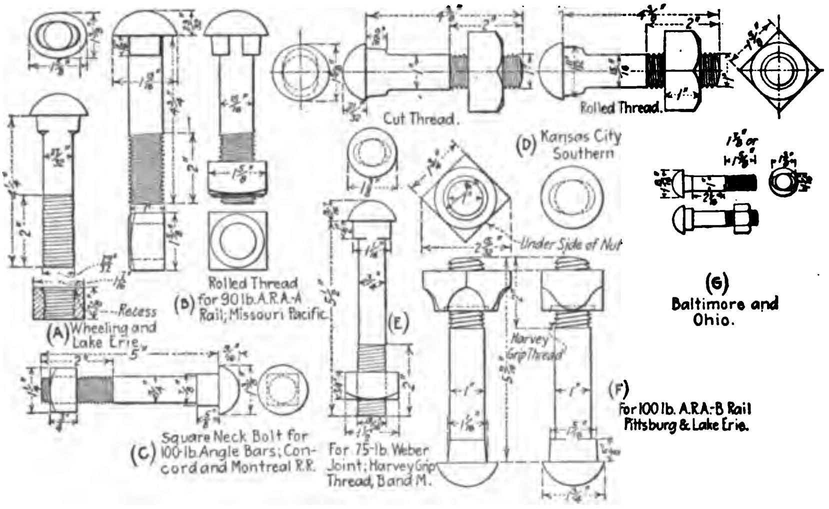

Cut Thread.
Rolled Thread.
(D) Kansas City Southern
Under Side of Nut
Recess
(A) Wheeling and Lake Erie
Rolled Thread
(B) for 90 lb. A.R.A.-A Rail; Missouri Pacific
(E)
Harvey Grip Thread
(C) Square Neck Bolt for 100-lb. Angle Bars; Concord and Montreal R.R.
For 75-lb. Weber Joint; Harvey Grip Thread, B. and M.
(F) For 100 lb. A.R.A.-B Rail Pittsburg & Lake Erie.
(G) Baltimore and Ohio.

FIG. 79.—Track-bolts.

heads (Fig. 79), and square or T-shaped flat heads. The round head is the most common. The neck of the bolt is usually made oval to fit an oval hole in the splice-bar so that the bolt will not turn as the nut is turned. A few railways use a bolt having a square neck, which fits a square hole in the splice-bar (Figs. 60 and 79*C*). Bolts are made of low-carbon steel, the maximum and minimum limits of carbon being about 0.25 and 0.15 per cent., respectively. The ultimate tensile strength specified varies from 52,000 to 70,000 lb. per square inch, and the finished bolt should stand hot- and cold-bending around its diameter through 180° without any sign of fracture on the outside.

The most common practice is to place the bolts in a joint with the nuts alternately on the inside and outside. The principal advantage of this is that in case of derailment the wheels will cut off nuts on one side of the rails only, leaving half the number of bolts to hold the rail temporarily. In some cases the nuts are all placed on the same side. This makes inspection easier, as all nuts can be seen from one side.

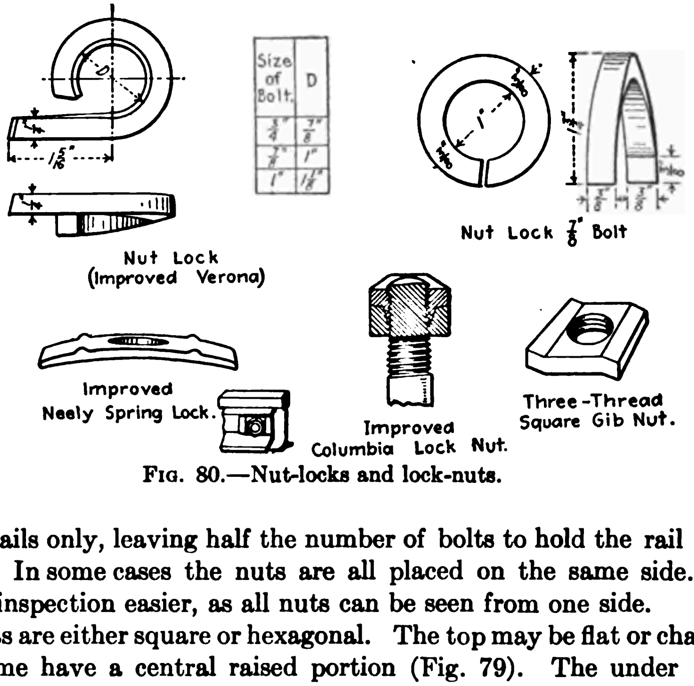


FIG. 80.—Nut-locks and lock-nuts.

Nuts are either square or hexagonal. The top may be flat or chamfered and some have a central raised portion (Fig. 79). The under surface must be flat to properly bear against the splice-bars. Splice-bars with large top ribs or heads may necessitate trimming the under corners of the nut to secure sufficient clearance (Fig. 79*F*). The nuts are $\frac{3}{4}$, $\frac{7}{8}$ or 1 in. thick and are from $1\frac{1}{16}$ to $1\frac{5}{8}$ in. square or of least diameter.

Bolts are shipped in kegs holding 200 lb. The average number of bolts and square nuts per keg is 106 for 1- by $4\frac{1}{2}$-in. bolts, 112 for 1- by $4\frac{1}{4}$-in. bolts, and 164 for $\frac{7}{8}$- by $4\frac{1}{4}$-in. bolts. The number of bolts required per mile for 33-ft. rails should be based on the number of joints per mile for an average rail length of 32 ft.

129. Nut-locks and Lock-nuts.—The action of traffic causes the bolts to work loose after a time. The Harvey grip thread shown in Fig. 79*A*, *E*, *F* and *G*, is designed to prevent this. Figure 79*A* shows the cross-section of a nut with this thread. The threads on the bolt are slightly undercut, that is, on the bearing side are less than 90° with the axis of the bolt. The nut is cut with exactly the same thread, but this results in the bearing side being an equal amount greater than 90°. A small V-shaped cavity with the point outward is thus left between the bearing sides of the threads of the bolt and nut. When the nut is screwed tight against the splice-bar, the sharp edges of the threads on the nut and the bolt are upset and tend to hook over or grip each other. This prevents the bolt from easily working loose. There is a shallow recess at the bearing surface of the nut which keeps intact the inner threads, upon which the nut can be screwed if it becomes necessary to tighten it.

Some form of spring nut-lock should be used with bolts having the U. S. Standard thread and ordinary nuts. In screwing the nut tight the spring is compressed so that a slight backward movement of the nut is taken up by the spring. The two nut-locks shown in Fig. 80 have been more widely used than all others. Another nut-lock and two lock-nuts also are shown in the figure. The improved Neely spring-lock combines a spring action with a locking action which two ribs on the spring exert against the edges of the nut. The Gib nut has three threads and combines the spring and cross-thread action against the nut. The improved Columbia lock-nut consists of two parts which together are the size of an ordinary nut. The locking feature is the wedging action of the tapered upper part against the lower part, and the cross-thread action of two nuts on the same bolt in jam-nut style. The improved Verona nut-lock of Fig. 80 weighs 0.083 lb.

CHAPTER X

TRACK FASTENINGS, CONTINUED

TIE-PLATES

130. Necessity for the Use of Tie-plates.—The failure of a tie results either from decay or from mechanical wear. Mechanical wear results chiefly from the tie being cut by the rail and the spikes being repeatedly redriven. These two forms of wear are called "rail-cutting" and "spike-killing." The softer the wood of the tie, the more easily it is damaged by these destructive agencies. Gritty ballast and the use of sand by the locomotive increase the wear. Injury to the tie can be very largely reduced, though seldom entirely prevented, by inserting a metal plate, called a tie-plate, between the tie and the base of rail. Wooden tie-plates have been used to some extent by European railways, but are not a success under the heavier wheel loads on American track. The advantages to be gained by the use of properly designed tie-plates are:

1. A reduction of the mechanical wear of the tie.
2. The tie-plate transmits the pressure on one set of spikes to those on the other side of the rail so that the spikes on each side of the rail act together.
3. Track holds gage better.

The disadvantages are:

1. The plates rattle when they are loose.
2. They may cut or indent the base of the rail.
3. They are often indirectly the cause of broken-base rail failures.
4. When the hole for a spike is injured and the spike must be driven or screwed in a different place, the other spike or spikes must also be removed and shifted, or a new hole must be drilled in the plate.

Rail-cutting of the tie is greater on curves than on tangents and, in any case, is greater on softwood than on hardwood ties.

The extensive use of treated ties has increased the use of tie-plates and other improved rail-fastenings. Since the life of the tie as limited by decay, is increased by the treatment, it is more necessary to protect the treated tie so that mechanical wear will not cause premature failure. If not used on all ties, in general, tie-plates should be used as follows:

(*a*) On all ties in tracks carrying heavy traffic.
(*b*) On all ties in high-speed tracks on curves of 2° or over.
(*c*) On all softwood ties.
(*d*) On all treated ties.
(*e*) On all switch-ties.

(*f*) Through road crossings and station-platforms.
(*g*) On all ties of turntables, ash-pits, trestles, and bridges.
(*h*) At water stations and track-tanks.

131. Development of Tie-plates.—The first tie-plates used were flat metal plates with holes punched for spiking. It was soon found that these plates, held only by the rail-spikes, worked loose and would rattle under the wave motion of the rail. As soon as this occurred the plate would pound the tie, and the tie would be cut almost as much as if plates were not used. Experience showed that the cutting of the tie by the tie-plate could be prevented only by fastening the plate firmly to the tie so that there could be no individual motion. This has led to various developments of the flat-bottom plate, such as the introduction of flanges, corrugations, or prongs on the bottom of the plate; intended to secure the plate to the tie. Not long after the invention of these improved plates the old flat-bottom plate practically disappeared, the Southern Pacific Co. being one of the few roads that continued its use to some extent. The increasing use of screw-spikes is now bringing the flat-bottom plate again into use.

132. Proper Design of Tie-plates.—In designing a tie-plate or adopting a certain plate for use on a railway it should be borne in mind that the purposes for which tie-plates are used, in order of importance are, (*a*) to distribute the direct pressure from the rail over a larger surface of the tie and to prevent pounding or cutting of the tie, (*b*) to assist the spikes in preventing the rails from spreading and from overturning. Many tie-plates fail as a result of buckling or cupping up on one or both sides of the rail. This is because the plates are too thin. Long plates or plates which have a wide projection beyond the edges of the rail must be thicker than short plates. The area of the plate must be such as to distribute the load from the rail over the tie with a good factor of safety. The plate should project not less than 2 in. beyond the base of rail on each side. Larger plates are required on softwood than on hardwood ties. Plates less than 7 in. wide cut into softwood ties. Longitudinal flanges on the bottom and grooves on the top give a stronger plate with less metal than a flat plate. Different patterns of tie-plates should be used to meet different requirements in the same track, as no one pattern can meet all requirements equally well. In 1910, one railway in the United States had in use eighteen different kinds of tie-plates, the difference being in type, size, or weight. Deep ribs or claws are not necessary to hold the plate to the tie, and they split or cut the wood and hasten decay.

Deep and sharp flanges, ribs, or claws are particularly objectionable on treated ties, as they cut through the most thoroughly treated part of the tie and allow moisture to reach the less thoroughly treated interior.

Plates with cross-ribs not over $3/16$ in. deep do not damage the tie and do not work loose. Corrugated and transverse-flange plates do not produce a tendency in the tie to split. When used under similar conditions with cut spikes they hold gage better than do flat-bottom and longitudinal-flange plates. Also, they can be more securely seated than longitudinal-flange plates if it becomes necessary to readjust the gage. Flat-bottom plates should be used only with screw-spikes because of the tendency to work loose and abrade the tie. Little advantage is gained by using flanged, pronged, or corrugated plates with screw-spikes.

Plates now in use are from 5 to 7 in. wide, from 7 to 11 in. long, and from ⅜ to ½ in. thick. A few are made ¾ in. thick. The plates at joints are 11 to 13 in. long, and where guard-rails are used the plates are from 14 to 25 in. long. The plates are made of cast iron, steel, or malleable iron. The experience of some railways has been that rolled-steel tie-plates rust out in about 4 years. In general, malleable iron and wrought iron give the best results.

European tie-plates have flat bottoms and are thicker and heavier than American plates. They depend entirely upon the rail-fastening for their attachment to the tie. Plates with pronged, flanged, and corrugated bottoms are strictly an American development.

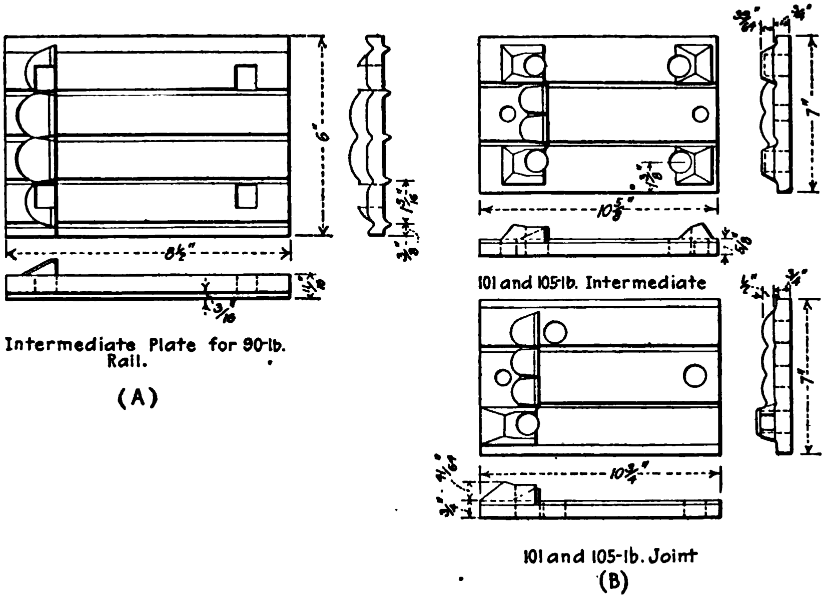
133. Classification of Tie-plates.—Tie-plates may be classified in two ways, namely, as to the form of the bottom, and as to the form of the top. The mechanical wear of the tie is mostly influenced by the form of the bottom, while the security with which the rail is held is influenced perhaps more by the form of the top. On a basis of the form of the bottom, plates may be classified thus: (*a*) Flat bottom. (*b*) Longitudinal flanged. (*c*) Pronged or hooked. (*d*) Transverse flanged or cross-ribbed. (*e*) Corrugated. On a basis of the form of the top, plates may be classified as follows: (1) Flat top. (2) Corrugated. (3) Single shoulder. (4) Double shoulder. (5) Hook. The top corrugations may be longitudinal, transverse or diagonal. Types (1) and (2) may be combined with (3), (4) or (5). Plates with grooved or corrugated tops were used on several German railways as early as 1840.

The shoulder may extend entirely across the plate, across only the middle part of the plate, or may consist of two lugs or short shoulders. A plate to be used with screw-spikes should offer a support for the outer edge of the head of each screw-spike. This support may consist of a continuous transverse top rib, or a raised bearing surface immediately outside each spike-hole. A modification of the flat-bottom plate is the cushion plate. This may have a shallow transverse groove 2 or 3 in. wide across the middle; or the entire bottom of the plate, except a narrow rim around each edge, may be depressed and used with or without a felt pad.

All of the improved types of tie-plates are patented. An investigation made in 1912 by the American Railway Engineering Association showed that of 61 railways reporting, the number of railways using the different types of tie-plates in order of numbers was as follows: (1) Longitudinal flanged. (2) Corrugated. (3) Transverse flanged. (4) Flat bottom. (5) Pronged.

Tie-plates are punched with two, three or four spike-holes. The wave motion of the rail tends to cause a flat-top plate to rock on the tie. For this reason several designs of plates have rounded corners and a few have the top cambered to an arc of large radius parallel to the rail.

134. Description of Plates in Use.—The Wolhaupter corrugated top, shoulder, flange tie-plate shown in Fig. 81*A* is a representative plate of the longitudinal-flange and corrugated-top type. These plates are made in a number of different patterns. The Wolhaupter shoulder flat-bottom plate used with screw-spikes on the Delaware, Lackawanna & Western R. R. is shown in Fig. 81*B*. On all intermediate plates the head of the screw-spike is supported on the outside by lugs. At joints, only one screw-spike is thus supported, the other two being placed in slots in the splice-bar. The small holes were for lag-screws which were to be used to fasten the plate to the tie, but several years of service showed that the bearing of the outer part of the spike-head against the raised shoulder or lug prevented the plate from rattling.



Intermediate Plate for 90-lb. Rail.

(A)

101 and 105-lb. Intermediate

101 and 105-lb. Joint

(B)

Fig. 81.—Wolhaupter tie-plates.

A plate of the corrugated-bottom and single-shoulder type is shown in Fig. 82. The plate illustrated is known as the Sellers Anchor Bottom plate. It is a wrought-iron plate and is rolled lengthwise of the plate or end over end. This places the fiber of the iron at right angles to the line of the rail. The plate, being of wrought iron, resists corrosion better than cast-iron and steel plates. The plates cost more than similar plates of steel but the scrap value of wrought iron is greater than that of steel. The ribs of the plate are shallow and do but little damage to the fiber of the tie. This plate was first manufactured about 1901 and since 1907 has been satisfactorily used in large numbers by many important railways.

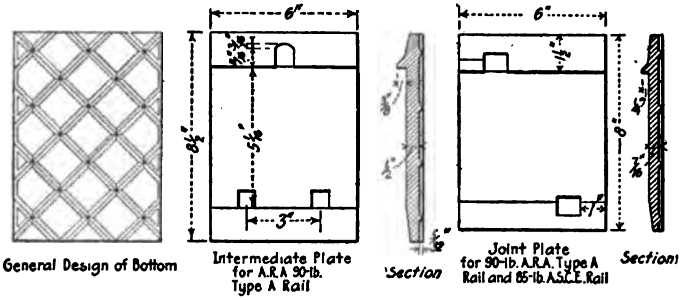

6"
8½"
5⅝"
3"
General Design of Bottom
Intermediate Plate for A.R.A. 90-lb. Type A Rail
Section
6"
8"
Joint Plate for 90-lb. A.R.A. Type A Rail and 85-lb. A.S.C.E. Rail
Section

FIG. 82.—Sellers Anchor Bottom tie-plate.

Plates of the longitudinal-flange single-shoulder type are shown in Figs. 83 and 88*B*. Transverse-flange plates are made with one to four flanges. Plates of this type are shown in Figs. 84 and 88*A* and *C*. A special combination or reversible transverse-flange shoulder plate is shown in Fig. 84*A*. With a certain side upward this plate is used for intermediate ties. When the plate is turned over, the transverse flange becomes a shoulder for the joint-plate while the shoulder for the intermediate plate becomes the flange for the joint-plate. The Clary plate is shown in Fig. 84*B*. It is a transverse-flange, corrugated-top, double-shoulder plate. Figure 85*A* shows the Harriman or Common Standard plate, which has a flat bottom, transverse top corrugations, and a single shoulder. The Le-

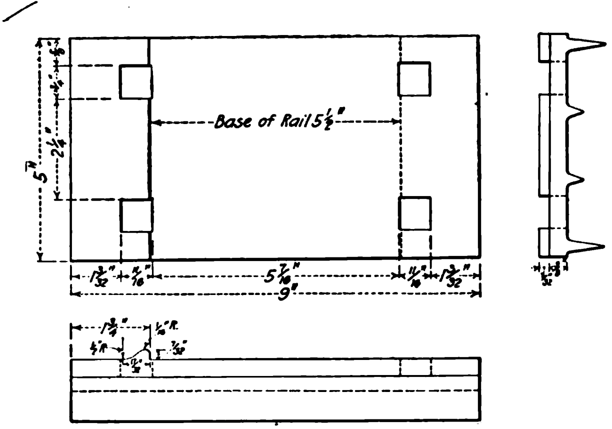
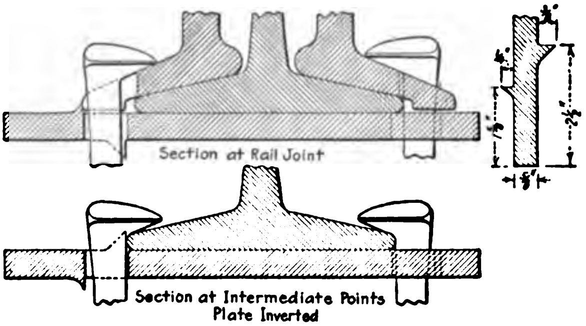
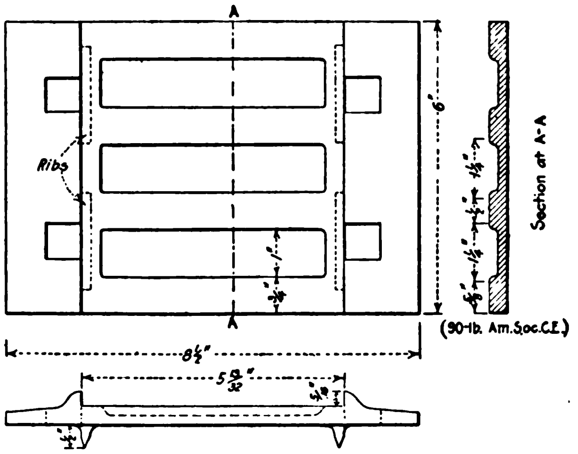


FIG. 83.—Longitudinal-flange shoulder tie-plate (B. & M. R. R.).

high Valley R. R. has used a transverse-flange plate having this same top. Figure 85*B* shows the so-called cushion-bottom plate. The Superior plate is shown in Fig. 85*C*. It is made to be used with a felt pad which is inserted in a recess in the bottom. Used without the pad it acts as a corrugated-bottom plate. The hook or hook-shoulder tie-plate used with screw-spikes on the Delaware, Lackawanna & Western R. R. is shown in Fig. 86. The plate may also be used with cut spikes. As used on the Delaware, Lackawanna and Western the plate is held to the tie by screw-spikes, while the rail is held on the outside by cut spikes and on the inside by the hook. The plate in the illustration is much heavier than ordinary tie-plates. Figure 69 is a photograph of a track installed with these plates. Hook plates are new in American track, but a tie-plate having a hook on one side which engaged the base of rail was tried some 10 years ago in Germany and was not entirely satisfactory. The hook, being rigid, can produce no real pressure against the rail-flange, so that most of



(A) P.R.R.



(B)

FIG. 84.—Transverse-flange tie-plates.

the stress must be borne by the spikes on the opposite side. In some cases where recently installed in American track a maul has been used to drive down the hook into contact with the rail-flange.

Two kinds of pronged tie-plates are shown in Fig. 87. That shown at (*A*) is the Goldie Claw tie-plate. The prongs or claws cut across the wood-fiber and the plate holds gage well but the fibers of the wood are damaged by the prongs. A plate with prongs parallel to the wood-fiber, used on the Erie Railroad, is shown at (*B*) and (*C*). One of these is for cut spikes and the other for screw-spikes.

The ordinary tie-plate has the rail-seat and the bottom of the plate parallel so that the web of the rail is perpendicular to the tie. With the present standard coning of car-wheels of 1 to 20 and a radius of 14 in. of the top of the rail-head, the point of contact of a new wheel on a new rail is about ¾ in. inside the center of the rail. This eccentric loading of the rail sets up unnecessary stresses in the rail and causes an unsymmetrical wear of the head. Observation of the shape of worn heads, particularly on the low side of curves, shows that the tendency is for the rail to wear to the shape of the wheel-tread. This can be overcome in a measure by canting the rail or inclining it inward an amount equal to the coning of the wheel. Canting is a common practice on European railways but has

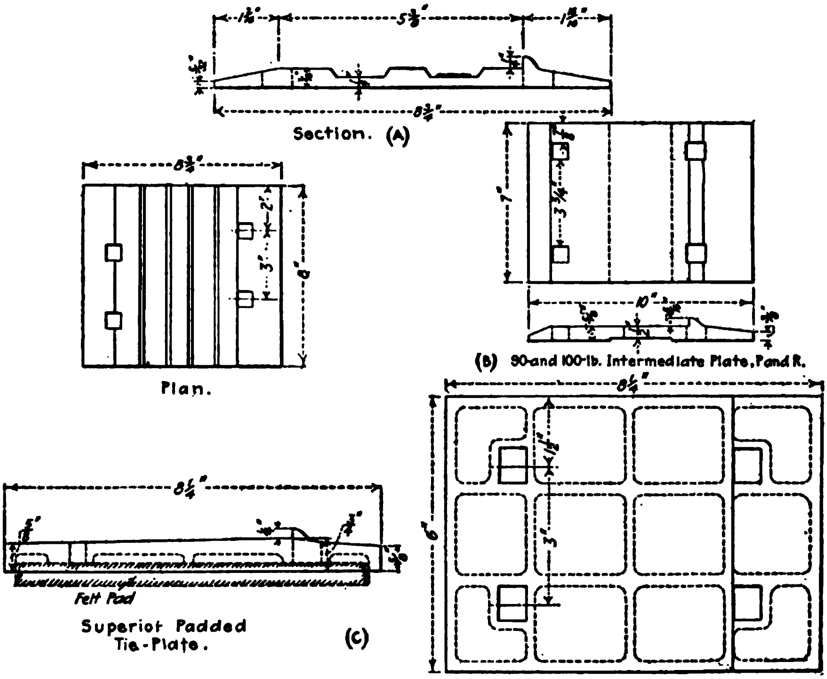

5¼"
8¾"
Section. (A)
8¾"
7"
6"
Plan.
10"
(B) 90-and 100-lb. Intermediate Plate, P and R.
8¼"
8¼"
Felt Pad
Superior Padded Tie-Plate.
(C)

FIG. 85.—Flat- and cushion-bottom tie-plates.

not been tried extensively in this country. However, trackmen for many years have practised this when laying rails, but it was done more to overcome the tendency of the rails to overturn or "roll out" than to shift the point of contact between wheel and rail. Canted tie-plates are now being used on several important railways. These are used under both rails on curves and tangents, or only on curves, or under only one rail on curves. The advantages to be gained by canting the rail are: (*a*) a reduction of the internal stresses resulting from eccentric loading; (*b*) reduced wear of the rail-head and wheel-flange; (*c*) uniform wear over the top of the head; (*d*) decreased tendency for the rails to spread and overturn. The disadvantages are: (*a*) all ties must be tie-plated; (*b*) difficulty encountered in connecting a canted rail to a vertical rail at switches, etc., and the introduction of torsion in the rail at such places; (*c*) flowing of the metal at the outer edge of the low rail on curves is increased because the point of contact between wheel and rail is shifted outward, this tendency being exaggerated by the false flange of worn wheels.

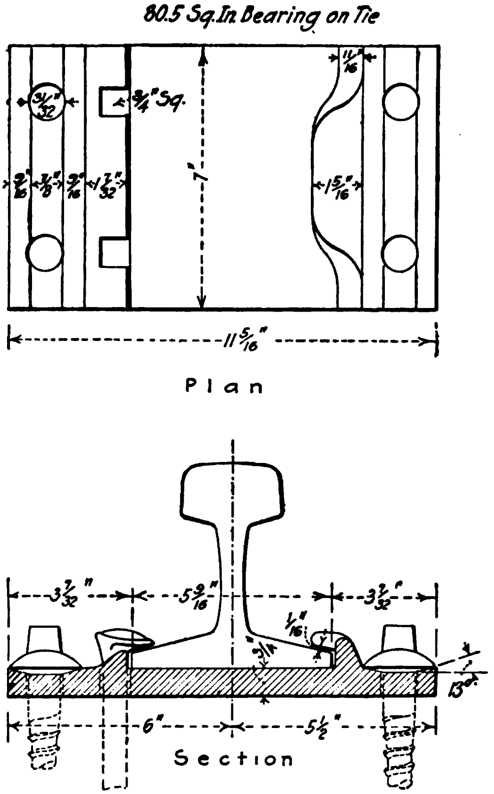
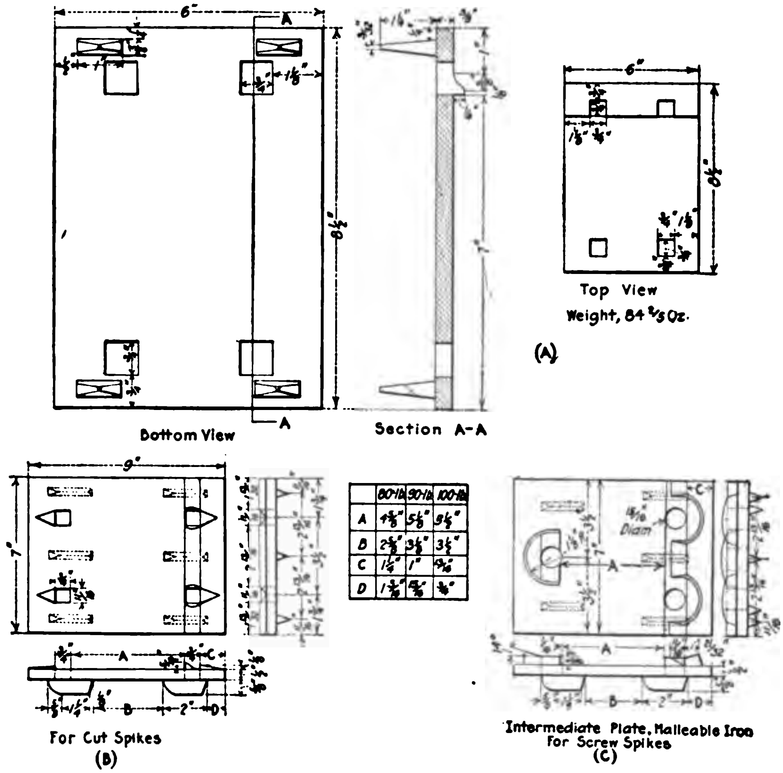


FIG. 86.—Hook-shoulder tie-plate (D. L. & W. R. R.).

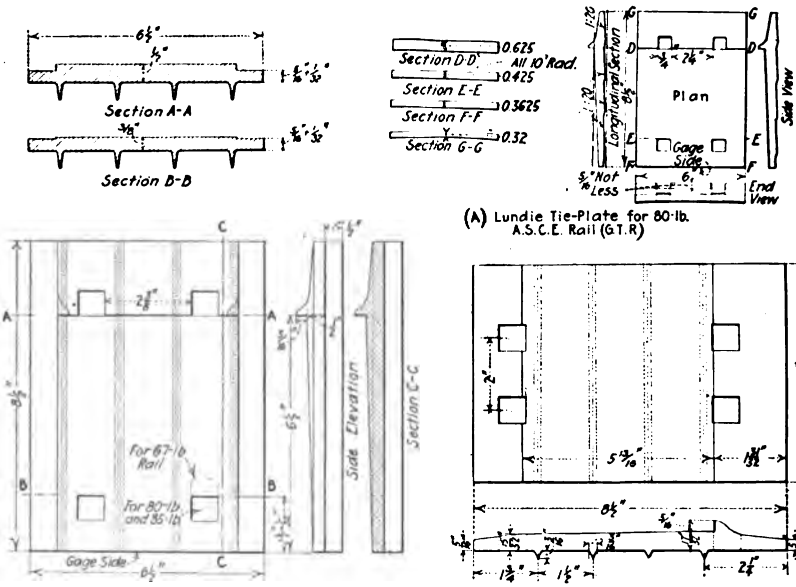
Three canted plates of different patterns are shown in Fig. 88. The Lundie plate (*A*) is unusual in several respects. The bottom is a modified form of a transverse-flange type, and consists of five inclined faces. The top of the plate is given an inward slope of 1 to 20, the bottom inclined faces are parallel to the top, and the distance between the top and each bottom face differs. The plate is cambered or crowned to a 10-ft. radius parallel with the axis of the rail, so that it does not present a sharp edge under the base of the rail as the load passes over it, and there is no tendency for the plate to rock. A canted, longitudinal-flange, single-shoulder plate used on the Canadian Government Railways is shown at (*B*), and the canted transverse-flange, single-shoulder plate of the Missouri Pacific Ry. is shown at (*C*), Fig. 88.



	80-lb	90-lb	100-lb
A	4⅝"	5⅛"	5½"
B	2⅝"	3⅛"	3½"
C	1¼"	1"	15/16"
D	1 3/16"	15/16"	¾"

FIG. 87.—Pronged tie-plates.

135. Combination and Compound Plates.—Several forms of these are being tried. The Betts anti-creeper tie-plate has a hook on each of two diagonally opposite corners. A spike-hole, made about twice as wide as necessary for the spike, parallel with the rail, is punched in each of the other two corners. The hooks slide over the base of the rail and creeping of the rail twists the plate about the spikes in the enlarged holes so that the rail-flanges are wedged in the hooks and further movement of the rail is prevented. A combination rail-brace and tie-plate is made by pressing one end of a flat steel plate into the form of a rail-brace and bending this slightly less than 180° upon the flat portion. When installed, the brace is on the outside of the rail and the flat part of the device extends under the rail and acts as a tie-plate. One form of combination plate consists of an upper and lower plate of about the same size. The plates slide under the rail from opposite sides. The rail is held on each side by a hook, one of which is on each plate, while the spikes do not bear against the rail.



(A) Lundie Tie-Plate for 80-lb. A.S.C.E. Rail (G.T.R.)

(B) Canadian Goverment Railways

(C) For 90-lb. A.R.A.-A Rail (Missouri Pacific)

FIG. 88.—Canted tie-plates.

The plates are interlocked by the spikes, which pass through both plates. In Germany and also in Italy experiments have been made with a plate or chair which is bolted to the rail-base and fastened to the tie with screw-spikes.

136. Installation of Tie-plates.—The value of tie-plates depends very largely upon the way they are placed under the rail. An improperly set tie-plate is a waste of money, because it damages the tie and defeats the object for which it is used. Accordingly, it is very important that the plates be given a complete and uniform bearing on the tie; that they be set square to the rail; that they have no motion independent of the tie; and that attention and care be given to placing them. Flat-bottom plates for cut spikes are the easiest of all to install. They can be slipped under the rail until the shoulder or shoulders engage the rail-base, the track can then be gaged, and the spikes can be driven in the holes of the plate. Flanged and pronged plates are difficult to apply. In all cases the ties should be adzed perfectly smooth in order to give an even bearing for the plates. Flanged plates are often installed by placing them under the tie and then driving down first one end and then the other end with a swage. This method is apt to skew the plate under the tie, or to get the shoulder of the plate either under the rail-flange or too far away from it. Plates of this kind should be seated with a device which straddles the rail and bears on both ends of the plate. Special machines are occasionally used to do this. In many cases the plates are secured to the ties before the ties are placed in the track. If this is done, a tie-plate template or gage must be used.

Tie-plates are punched right-hand and left-hand. In some cases a right-hand plate is put on one end of the tie and a left-hand plate on the other end. In other cases two right-hand and two left-hand plates are placed on alternate ties.

When trackmen are installing pronged or flanged tie-plates, the tendency is for them to place the plates under the rail and leave them to be seated by the first passing train. This should never be done, because dirt is likely to get under the plate in the meantime. The plates should always be seated when they are installed.

TRACK-SPIKES

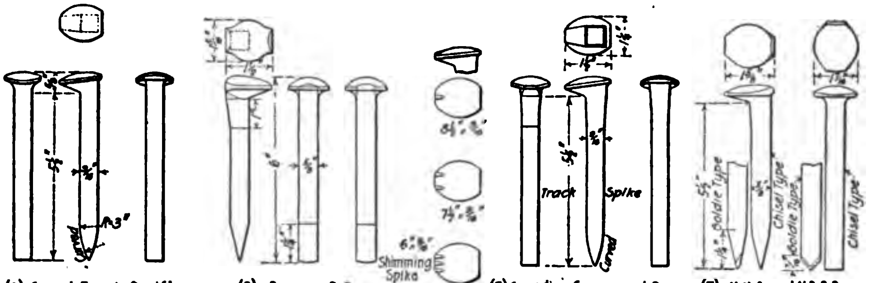
137. Common Spikes.—The functions of the spike are:

(*a*) To hold the rail to the tie, particularly if the tie is softwood.
(*b*) To prevent the rails from spreading laterally.
(*c*) To prevent the rails from overturning.

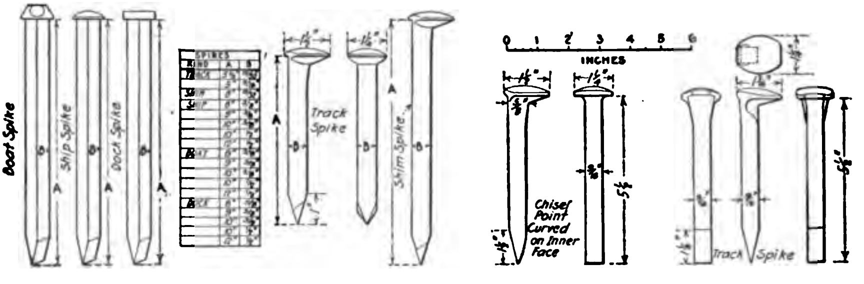
Except for a comparatively small number of screw-spikes, ordinary nail-spikes, called common spikes or cut spikes, are used universally in America. These spikes have cross-sections which vary from ½ to ⅝ in. square. Their length is from 4½ to 6¼ in. under the head. The most commonly used size is 5½ by 9/16 in. Spikes ½ in. longer are used with tie-plates. Several kinds of spikes are shown in Fig. 89. Track-spikes are made with chisel (*A*, *C*, *E*, and *G* of the figure), rolled (*B*), and sharp points (*D* and *F*). The point may be parallel to or perpendicular to the grain of the tie. The latter is best as there is less tendency to split the tie. The point is ¾ to 1¼ in. long and in some cases one (*C*) or both (*A* and *E*) faces of the point are made convex to a radius of about 3 in. The body of the spike may be of uniform section from head to point (*A*); or may have a neck 1 to 1¼ in. long which flares in the front (*C* and *D*), in the back (*B*), or on all sides (*E*). The bottom of the head must have the same slope as the fishing angle of the rail-base.

Shim-spikes (*D* and *E*), which are longer than ordinary spikes, are used for fastening shims to the tie. The heads of these should be marked in some way to show the length, as in (*E*). The length of a spike should be at least 1 in. less than the thickness of the tie. Longer spikes may split the tie.

138. Material, Weight, and Strength of Common Spikes.—Spikes are made either of wrought iron or of soft steel. For wrought-iron spikes the Delaware, Lackawanna and Western specifies a minimum ultimate tensile strength of 48,000 lb. per square inch. The specified ultimate tensile strength per square inch for steel is as follows: Delaware, Lackawanna and Western, not less than 60,000 lb.; New York Central and Hudson River, not less than 50,000 lb.; Baltimore and Ohio, between 55,000 and 65,000 lb. The carbon in the steel is about 0.15 per cent.



(A) Grand Trunk Pacific (B) Penna. R.R. (E) Canadian Goverment Rys. (F) N.Y.C. and H.R.R.R.



(D) Boston and Maine (C) B. and O (G) Kansas City Southern

FIG. 89.—Common spikes.

Spikes are shipped in kegs containing 200 lb. The number of spikes contained in one such keg is 230 6½- by ⅝-in., 262 6- by ⅝-in., 340 5½- by 9/16-in., and 360 5- by 9/16-in. The number required per mile depends on the number of spikes per tie and the spacing of ties.

Common spikes driven in bored holes do not seriously damage the wood-fibers and in most woods the resistance to pulling is greater than for driven spikes. Common spikes to be driven in bored holes should have sharp or diamond points. If the spikes are driven, sharp-pointed spikes offer a greater resistance to pulling than chisel-pointed spikes.

The resistance to pulling of driven, common spikes varies from about 2500 lb. in soft pine to about 6500 lb. in white oak. It appears that spikes corrode to a greater extent in ties treated with zinc chloride than in other ties.

139. Installation and Wear of Common Spikes.—Spikes should never be "driven to pull," that is, leaned away from the rail when first started and drawn to a vertical position while being driven, but should be driven vertically. Spikes should not be driven nearer than 2 in. to the edge of the tie, nor opposite on each side of the rail because of the liability to split the tie. On bridges the spikes should not be driven in the splice-bar slots or holes because of the expansion and contraction of the structure.

Four, six, or eight spikes per tie are used. When six are used two are usually placed on the inside and one on the outside of each rail. The standard spiking per tie of the Pennsylvania Railroad is as follows: (*a*) At each rail on tangents without tie-plates, one spike inside and one outside. (*b*) On tangents where flat or ribbed tie-plates are used, two spikes inside and one outside at each rail. (*c*) On curves where flat or ribbed plates are used, two spikes inside and two outside at each rail.

If the rail is not firmly clamped to the tie the sawing action of the flange wears away the inside of the spike under the head. A spike showing wear of this kind is said to be "necked." The object of the flare of the neck is to provide additional strength at this place. If the neck is badly cut the head is likely to shear off. If a number of the spikes holding a rail have become slightly lifted, leaving only a few which bear firmly against the rail, the stress from a passing train is often sufficient to shear off the heads of the low spikes, even if the spikes are new.

140. Objections to Common Spikes.—There are several objections to common spikes, the most important of which are: (*a*) Passing trains produce an undulatory movement of the rail which gradually lifts each spike out of the tie. (*b*) They tear and badly damage the wood-fibers for an inch or so around the spike. (*c*) As soon as the spike has been lifted enough to reduce its pressure on the rail, the wave motion causes the rail to creep. (*d*) When the spike is lifted sufficiently far to be noticed, it is driven down again. A second time it will be lifted easier than before. This results in repeated redriving of the spikes, until in time the spike-hole becomes enlarged, admits moisture to the center of the tie, and hastens decay. (*e*) Eventually the spike becomes so loose that it must be withdrawn and driven in a new place. This often repeated fills the tie with holes to such an extent that no sound wood remains in which to drive the spike; the tie is then said to be spike-killed, and must be removed. (*f*) If there is danger of the narrow longitudinal flanges and prongs of tie-plates splitting the tie, how much greater must be that danger from driven, cut spikes.

Lateral pressure on the spike aids in enlarging the hole and reducing the holding power of the spike. The objections to the cut spike are greater for softwood than for hardwood ties, because the softwood offers less friction to the drawing of the spike, and the wood-fibers are damaged to a greater extent. As the percentage of softwood ties to all ties used is constantly increasing and the price of all ties is steadily rising, the use of a better rail-fastening than the common spike is of increasing importance.

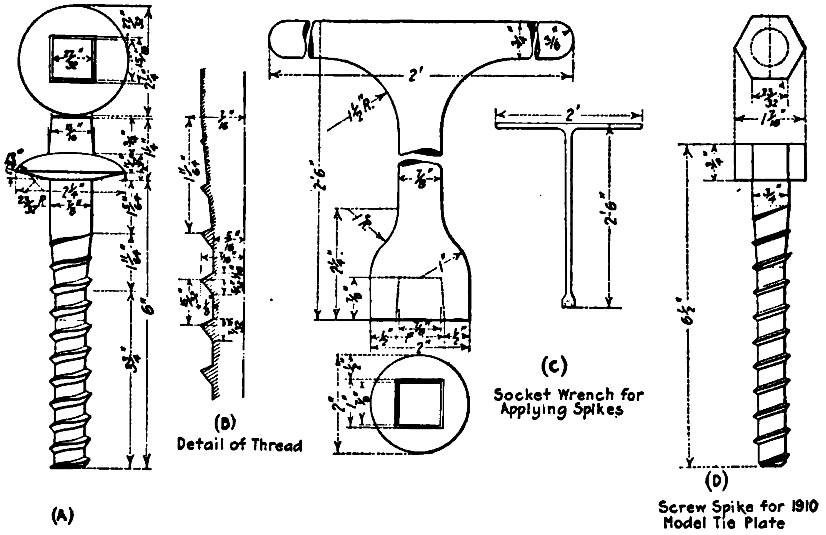
141. Tie-plugs.—A tie-plug is a wooden peg having the same length and cross-section as a track-spike, and is used to plug up the hole from which a spike is withdrawn. Tie-plugs are machine-made from different woods. The invariable rule should be to plug every hole wherever a spike is drawn, except when the tie is to be renewed that season. When it is necessary to redrive a spike, it should be driven into the plug and not weaken the tie by making a new hole.

142. Rail-fastenings Other than Common Spikes.—The objections to common spikes, enumerated in Art. 140, have led to the limited use of screw-spikes on American railways. Development of this form of rail-fastening commenced about 1860 and their first use appears to have been made on the French railways. Screw-spikes are now universally used by all important French, Belgian, and German railways. In England screw-spikes are even less used than in the United States, a few only being used on the London and Northwestern. The general English practice is to fasten the rail-chairs to the ties by using two round, blunt-point spikes, and two wooden trenails, or two screw-spikes (Fig. 103) which are inserted in previously bored holes. The Great Western Railway uses bolts extending entirely through the tie. Bolts are used universally to fasten the rail to substitute ties.

143. Screw-spikes.—The advantages of the screw-spike over the common spike are several. It does not damage the wood-fiber of the tie. Its holding power is from 1½ to 2½ times that of the common spike; hence it remains in position after being installed, and maintains a constant pressure on the rail-base. The general result is a decreased mechanical wear of the tie, both from spike and tie-plate, and a stronger and easier-riding track.

Though superior to the common spike, the screw-spike is not in all respects an ideal rail-fastening. In the course of time it is found that screw-spikes may work loose in and enlarge the hole. If a screw-spike breaks, it is impossible to remove the stump from the hole. It is very expensive to regage track where screw-spikes are used. Larger tie-plates are required with screw-spikes than with common spikes. It is more difficult to renew rail, or remove broken rails held with screw-spikes than with common spikes.

144. Form of Screw-spikes.—Many forms of screw-spikes have been tried. The tendency now is toward the adoption of the form shown in Fig. 90 (*A*). This is the type used in 1915 by the Delaware, Lackawanna and Western. A detail of the thread is shown at (*B*) and the socket wrench for applying the spikes is shown at (*C*). These spikes are made from open-hearth steel bars and their allowable minimum tensile strength is 60,000 lb. per square inch. Spikes of this form have a mushroom head with a raised square center to provide a grip for the wrench. A track installed with these is shown in Fig. 69. The under surface of the head is given the slope of the base fishing angle of the rail. A form of screw-spike used on the Pittsburgh and Lake Erie is shown at (*D*). This has a hexagonal head which is flat on the top and bottom. Screw-spikes are used in the following three ways in American track: (1) The mushroom head of the spike bears directly on the rail-flange; hence the under side must have the same slope as the rail-flange. (2) The screw-spikes are used to hold the tie-plate, the rail being held with common spikes or a common spike and a hook shoulder on the tie-plate. (3) The rail is held by clips which are held by screw-spikes (Fig. 91*C*). In the latter case the bottom of the head can be flat. The first method mostly is used. If the spike bears directly on the rail it is very important to support the outer edge of the spike-head by a shoulder or lug on the tie-plate. If this is not done the spike will be bent outward, releasing its hold upon the rail and allowing the rails to spread. For this reason the best results cannot be obtained by using screw-spikes without tie-plates.


(A)

(B) Detail of Thread

(C) Socket Wrench for Applying Spikes

(D) Screw Spike for 1910 Model Tie Plate

FIG. 90.—Screw-spikes.

The diameter of the spike depends upon the number of spikes used per tie. If three spikes instead of two are used at each rail-seat the spikes can be smaller. Since the spikes are inserted in bored holes the length of the spike can be anything less than the thickness of the tie. In America the diameter of the mushroom head is from $1\frac{7}{8}$ to $2\frac{1}{4}$ in.; the diameter of the neck is from $\frac{3}{4}$ to $\frac{31}{32}$ in.; the diameter of the body is from $\frac{1}{2}$ to $\frac{23}{32}$ in.; the length under the head is from $4\frac{7}{8}$ to 6 in. Laboratory tests indicate that the form of thread has little effect upon the resistance of the spike to pulling.

145. Installation, Maintenance, and Service of Screw-spikes.—The boring of the holes for screw-spikes may be done by hand, but if many ties are to be bored the work can be done to better advantage by using special tie-boring machines. All boring and adzing must be done before the tie is treated. If it is necessary to bore a hole in a treated tie the hole should be filled with hot creosote oil before the spike is inserted. The method of applying screw-spikes varies according to traffic conditions and the number to be installed. A small number can be applied best by hand, while power-machines are used for large installations. Some power-machines are operated by steam and are mounted on special flat cars. Others are operated by gasoline and are mounted on light hand-cars so that they can be lifted from the track and do not impede traffic. Some of the gasoline machines are self-propelling. When applied by hand, the spike is driven with a hammer far enough for the threads to take hold. The spike is then screwed down with a key wrench.

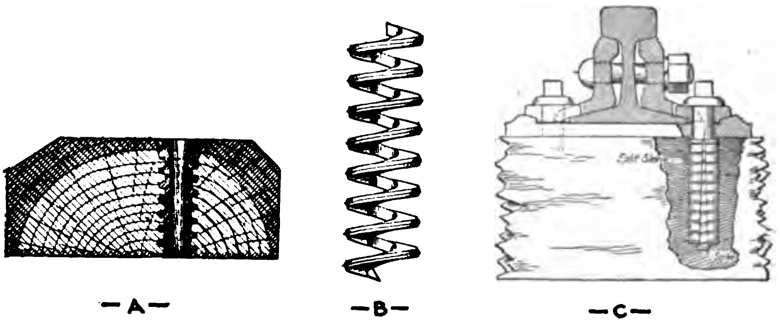


FIG. 91.—Linings for screw-spike holes.

If the spike works loose in the hole it becomes necessary either to restore the hole in some way or to move the spike to a new hole. Several devices for restoring spike-holes have been tried with some success. These consist of a lining of wood or metal which is inserted in the hole and into which the spike is then screwed. Three devices of this kind are shown in Fig. 91. The wooden trenail (*A*) is a threaded, hollow, wooden plug intended to be screwed into the spike-hole, which must previously have been enlarged for it. Afterward the spike is screwed into the trenail. The objection to the trenail is its diameter, which is so large as to weaken the tie. The Thiollier helical lining (*B*) is a spiral steel spring, which is screwed into a thread in the spike-hole. The Lakhovsky lining (*C*) is a split metal sleeve, which is inserted in the hole. It forms a threaded socket for the screw-spike and, as the spike is screwed down, the sleeve is spread outward against the wood.

In 1915, screw-spikes were in service in the United States on about 1500 miles of track distributed among some fifteen railways. The Atchison, Topeka & Santa Fe Ry. was the pioneer in using them in large numbers in this country. In 1907, the Pennsylvania R. R. installed screw-spikes on a test-section of track 2 miles in length, near Scio, Ohio. Those first installed were similar to those in common use in France, and were used with Thiollier helical linings. In 1910, it was necessary to renew all joint-spikes, and these were replaced with larger spikes and Lakhovsky linings. The track was so badly out of gage in 1913 that regaging was necessary. As it was necessary to use common spikes in regaging, the experiment was thus terminated. From 1910 to 1913 an accurate record was kept of all maintenance costs. These are shown in Table 13. In this test the cost of maintaining the screw-spikes was from two to three times that for cut spikes.

Screw-spikes have been used by the Delaware, Lackawanna & Western R. R. in all main-track new construction and maintenance since 1909. Over 12,000,000 were used from 1910 to 1914 inclusive. The following is an abstract of the conclusions drawn by Mr. G. R. Ray, Chief Engineer, Delaware, Lackawanna & Western R. R., after more than 4 years' careful observation of these spikes in service.[1]

TABLE 13.—COST OF MAINTENANCE PER FOOT OF TRACK ON EXPERIMENTAL TRACK, SCIO, OHIO (P. R. R.)

February, 1910, to January 31, 1913

Type of track	Surfacing	Lining	Gaging	Tightening rail-fastenings	Renewing rail-fastenings	Tightening joint-bolts	Renewing joint-bolts	Total labor	Cost of material used in renewal	Grand total
Treated Red Oak Ties— Screw-spikes, linings and tie-plates.	0.3332	0.0372	0.0093	0.0231	0.1240	0.0006	0.0036	0.5309	0.2887	0.8196
Treated Red Oak Ties— Screw-spikes and linings	0.1651	0.0413	......	0.0365	0.0964	......	0.0011	0.3405	0.3419	0.6824
Treated Pine Ties— Screw-spikes, linings and tie-plates.	0.1502	0.0483	0.0069	0.0222	0.0880	0.0014	0.0020	0.3190	0.3376	0.6566
Treated Red Oak Ties— Common spikes	0.1730	0.0081	0.0028	0.0299	0.0023	0.0034	......	0.2195	0.0035	0.2230
Treated Red Oak Ties— Common spikes and tie-plates.	0.1211	0.0493	0.0088	0.1367	......	......	......	0.3159	......	0.3159
Treated Pine Ties— Common spikes and tie-plates.	0.2045	0.0021	0.0026	0.0277	......	......	......	0.2369	......	0.2369

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[1] Bulletin 175, American Railway Engineering Association, page 301.

1. The size of screw-spikes and the design of the thread should be carefully considered before a screw-spike is adopted. Thereafter no changes should be made; otherwise the new screw-spikes cannot be used in old holes without damaging the wood-fiber.
2. Where salt-brine drippings are excessive, screw-spike heads must be made sufficiently large; otherwise there may be difficulty in the future in removing the screw-spikes from the track, due to corrosion.
3. The screw-spike head should have tapering sides to prevent turning in the wrench socket after the size of the head has been diminished by rust.
4. Any mechanical device for setting down screw-spikes must automatically release when the screw-spike is seated; otherwise the screw-spike is apt to be damaged in the case of hardwood or the wood-fibers destroyed in the case of softwood.
5. Very little trouble is experienced by screw-spike heads breaking off, either on account of track movement or derailed equipment. The heads are, at times, damaged to considerable extent by derailments, but as a rule the spikes are not broken, nor is their holding-power affected.
6. When screw-spikes are fully seated, no further strain should be put on them, as this will tend to destroy the threads in the wood or injure the spikes.
7. All ties should be bored at the treating plant before treatment. This can be done while the ties are being adzed, and not only insures that the holes are bored sufficiently deep, but provides for good treatment of all wood adjacent to the spike-holes.
8. Where the ties are bored before treatment, the track must be to proper gage before the ties can be placed.
9. The holes for screw-spikes should be of proper dimensions for the class of wood used, with due regard to the size of screw-spike used.
10. A limited number of holes can be bored with one bit, after which its size will diminish so as to make it unfit for a hole of a given size.
11. Holes should be bored somewhat deeper than the length of the screw-spike. There is no serious objection to boring the holes entirely through the ties.
12. Not only is the lateral and vertical resistance of a screw-spike greater than that of a cut spike when both are first applied, but the lateral and vertical resistance of a loose screw-spike is considerably greater than the lateral and vertical resistance of a loose cut spike.
13. When the threads in the tie are entirely destroyed, a screw-lining (any one of several different varieties) may be used with good results.

On approximately 60 miles of the Lackawanna Railroad of New Jersey the cost of boring the ties by hand in the field was 3.5 cts. per tie bored with four holes. Applying the screw-spikes cost 1.9 cts. each. Boring and adzing the ties before treatment has cost about 1½ cts. per tie. The average cost of applying screw-spikes in installations of the New York, New Haven & Hartford R. R. and on the Baltimore and Ohio R. R. was 0.7 and 1.1 cts. per spike, respectively.

RAIL-ANCHORS

146. Rail Creeping.—The creeping of rails results from one of two things: (1) the wave motion of the rail caused by the passage of each set of wheels of a train; (2) the continued or excessive use of brakes when approaching stations or on grades. Creeping due to wave motion is the more common. The amount of creeping depends largely upon the condition of the track and roadbed. On well-ballasted track with heavy rails and a solid roadbed creeping is never excessive. There is always more or less creeping of light rails in a thinly ballasted track. In each case a springy roadbed greatly increases the tendency of the rails to creep. Creeping is always greater on embankments than in cuts. The worst cases have occurred on soft embankments across marshy ground. With the increase in weight of equipment and the increasing mileage of double track the problem of rail creeping has become more acute. Traffic on single track has a tendency to equalize rail creeping; hence rail-anchors or anti-creepers are not extensively used on single track except on grades and curves, or where expansion is severe because of extreme temperature variations, or where the roadbed is soft. On single track the creeping occurs in the direction of the heaviest traffic.

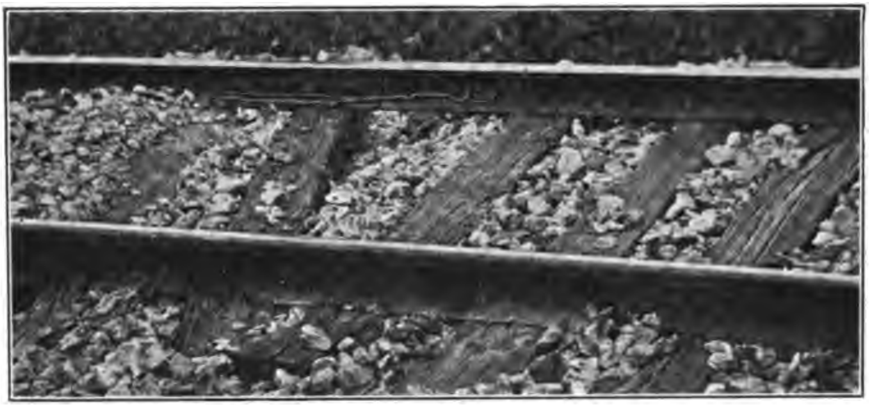

Fig. 92.—Joint-ties skewed by rail creeping.

The effects of creeping rails are: (1) The skewing of the joint-ties where the splice-bars extend below the base of rail or are slot-spiked to the ties. These are pulled ahead on one end, making a long span for the rail on one side of the joint and bunching the ties on the other side of the joint. A condition of this kind is shown in Fig. 92. (2) Expansion spaces between the ends of rails are closed up so that when the rails expand they will bend laterally or vertically. Driving back the rails to get expansion spaces must often be resorted to when this occurs. (3) Crossing frogs are pushed out of line. At double-track crossings the trouble is doubled, as the frogs on each track are pushed in opposite directions. (4) Switches, movable-point frogs, interlocking fixtures, and draw-bridges are jammed and rendered inoperative.

In some cases creeping is so bad that it is necessary to use compensating switch-points to take up the movement. Across the muskegs of Canada creeping is very severe. Prior to 1904 a section of track of the Lehigh and Hudson River Railroad across constantly wet meadows between Sand Hill, N. J., and Verona, laid with 65-lb. rails, was observed to creep as much as 13 ft. in one week. The movement of an individual rail under a heavy train was as much as 2½ in. In 1904, 80-lb. rails were laid and in 1909 these were renewed with 100-lb. rails. The wave motion of the entire fill due to the passage of a train was shown by the astonishing fact that during the three months between the time the 100-lb. rails were unloaded alongside the track and the time they were laid, these rails showed a pronounced tendency to move along the top of the fill in the direction opposite to heaviest traffic. The movement of some of these rails during that time was 70 ft.[1] A creepage of 80 ft. during one summer has been observed on one railway where the track is over very marshy ground. In general, a movement of 14 to 18 in. a year is considered excessive. A movement of 4 to 6 in. in a year makes the use of rail-anchors an economy.

147. Rail-anchors.—The requirements of a rail-anchor are: (1) It must effectually prevent creeping. (2) Its first cost must be low. (3) It must be simple in construction, easily applied, and require a minimum of maintenance. (4) It must be strong enough to withstand the severe stresses placed upon it. (5) It must maintain a firm grip on the rail at all times, even if the rail backs up slightly.

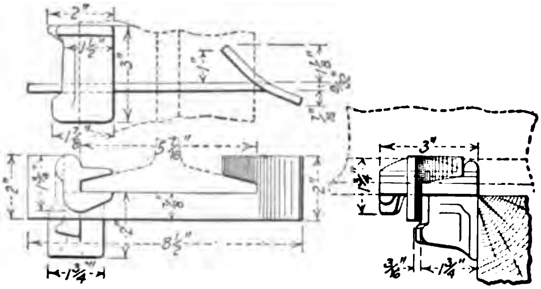

FIG. 93.—Vaughan rail-anchor.

On a large number of roads the spikes in the slots of the splice-bars are relied on to hold the rail, but, as shown in Fig. 92, this usually is not successful. It is better to overcome the creeping by the use of anti-creeping devices. A short piece of angle-bar bolted to the rail and slot-spiked to the tie was one of the first rail-anchors used. It is objectionable because it necessitates drilling the rail while the rail is in the track. No single anchor which is not bolted to the rail and spiked to the tie will prevent movement in either direction. However, as a reverse movement is very unusual it is far better to prevent creeping by the use of an anchor which bears against the side of the tie and thus offers the resistance necessary to prevent creeping, but which in no way is fastened to the tie. The failure of rail-anchors is frequently due to their not having been applied properly.

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[1] Rail Creeping on Wet Subgrade, Railway Age Gazette, Nov. 17, 1909.

The earlier patented anchors were of the bolted type, consisting of hooks which engaged each flange of the rail and which were connected by a bolt under the rail. Tightening the bolt clamped the hooks to the rail-base. A lug on one or each of the hooks bore against the side of the tie and acted as the anchor. Since all bolts in a track eventually work loose, this type of anchor was unsatisfactory. It is now considered obsolete.

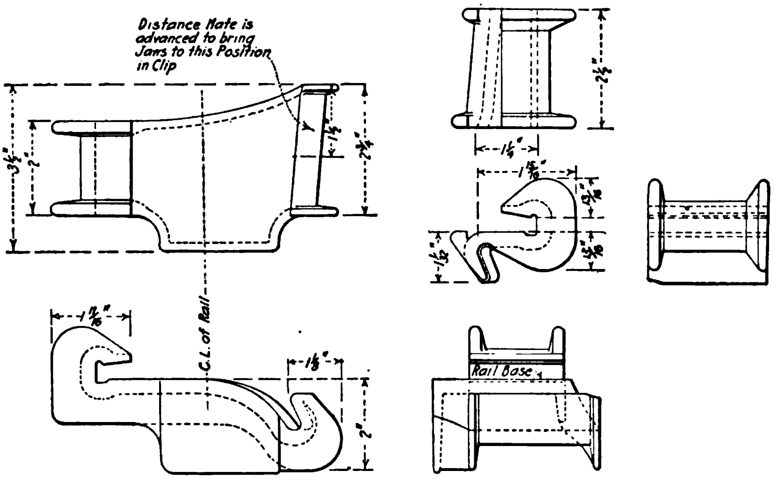


FIG. 94.—P. and M. rail-anchor.

The most successful patented anchors are those of the wedge type. Several of these have a combined wedge and spring action. The Vaughan, the P. and M., the Positive, and the Superior represent the best types now in use. The first three are older and have been used very extensively. The Vaughan (Fig. 93) and the P. and M. (Fig. 94) are two-piece anchors, while the Positive (Fig. 95) and the Superior (Fig. 96) are one-piece anchors. The Vaughan and the Superior have the combined wedge and spring action and are very similar in principle. The Vaughan anchor consists of a spring-steel yoke extending across and under the rail-base, and a malleable-iron shoe. The yoke has a twist of 15°. One end is hooked and engages the edge of the rail-base; the other end is square and engages a slot in the iron shoe. The two parts are held together by the reaction of the twist in the yoke, the twist being taken up when the shoe is applied. The hooked end of the anchor is driven toward the tie until the device has a firm grip upon the rail-base. A tendency for the rail to creep merely increases this wedging action and tightens the grip upon the rail. The working principle of the Superior anchor is the same. The P. and M. anchor consists of two pieces, each hooking over one edge of the rail-base and the two pieces being interlocked under the rail. Through a wedging action of one piece upon the other where they interlock, a movement of the rail tightens the grip of the device upon the rail. The Positive anchor consists of a single piece which grips the rail-base by a wedge action similar to that of the Vaughan and Superior anchors. After being installed it is locked on the rail by hammering down a lug on one of the hooks. This anchor, tested at the United States Navy Yard at Norfolk, Va., in Feb., 1914, showed a movement of the rail with respect to the tie for various pulls applied to the rail as follows: at 6000 lb., the rail moved 1/16 in.; at 9000 lb., the rail moved 1/4 in.; at 11,000 lb., the rail

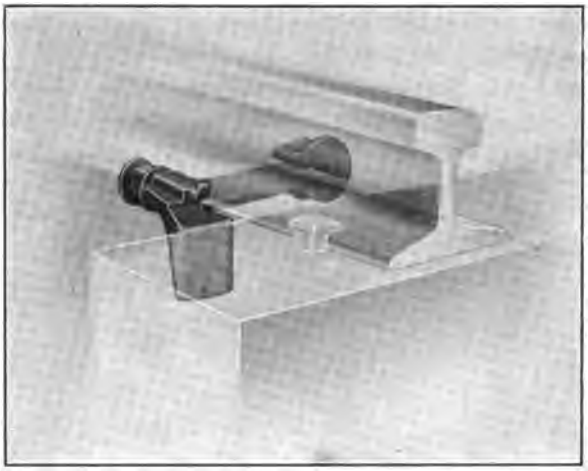


FIG. 95.—Positive rail-anchor.

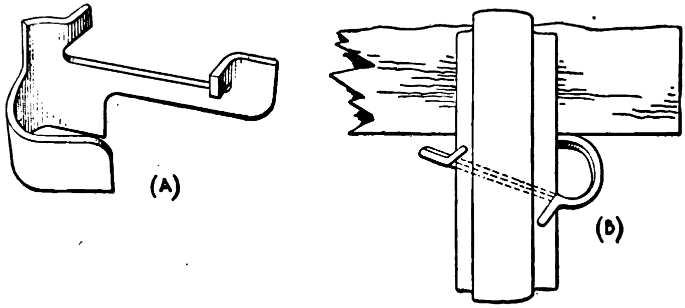


FIG. 96.—Superior rail-anchor.

moved ¾ in. The movement resulted from the tie-abutting side of the device moving laterally on the rail and from the compression of the wood under the bearing shoulder. There was no movement of the rail through the anchor. The Dorpmueller, a German anchor which has been used to some extent on the New York Central, Missouri Pacific, and Delaware, Lackawanna and Western, is shown in Fig. 97.

On the Ohio River cantilever bridge of the Pittsburgh and Lake Erie creeping is prevented by using wide-flange splice-bars bolted to the rail with five bolts and fastened with two screw-spikes per tie to five ties spaced 3 in. in the clear. Short pieces of 3- by 4-in. angles are bolted across the bottom of the rail-base between alternate ties. The back of the 4-in. flange bears against the side of the tie opposed to the direction of creeping. These fixed points are 769 ft. apart on the channel span of the bridge. Intermediate rails are carefully laid to allow for expansion.

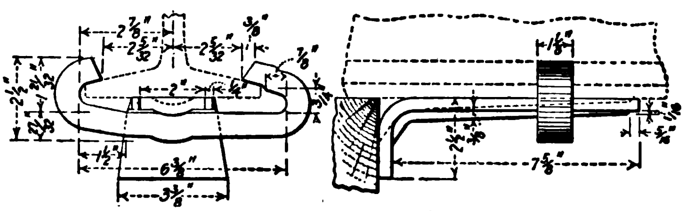


FIG. 97.—Dorpmueller rail-anchor.

148. Economy in the Use of Rail-anchors.—The number of anchors required per rail depends upon the severity of the creepage and is from two per rail to one for each tie per rail. Less than two per rail should not be used. If there is a movement of the rail in each direction, twice the ordinary number of anchors are necessary. The track shown in Fig. 92 is the east-bound track of a double-track line. Both tracks were surfaced about 6 months before the photograph was taken. Surfacing cost about $300 per mile of line. The west-bound track was anchored at a cost of about $225 per mile of track, while the east-bound track was not anchored. When this photograph was taken the west-bound track was still in perfect condition. To resurface the east-bound track would cost from $150 to $200 per mile of track. The cost of a rail-anchor is from 15 to 25 cts. The cost of application is from $10 to $50 per mile, depending on the type of anchor and number used. Four anchors per 33-ft. rail are frequently used. This would require 1280 anchors per mile of track. The cost of installing these would be about $20. If the splice-bars are slot-spiked to the joint-ties and two anchors are used per rail, the two anchors should be placed at the middle of the rail on the joint-ties of the opposite rail. If four anchors per rail are used two are placed in the above-mentioned position and one each midway between these two and the ends of the rail. Where anchors are applied on other than slot-spiked joint-ties they should be applied to each end of the tie to prevent skewing it. It is useless to place a large number of anchors on the rails within a few hundred feet of railroad crossings, turnouts, or bridges, or at the bottom of a hill, if the track back of these is unanchored. The track must be anchored where the creeping originates and not alone where the results are most apparent. Since it is the ballast that ultimately resists the tendency for an anchored rail to creep, rail-anchors are most effective in well-ballasted track. However, the ballast should not come into contact with the anchor.

OTHER TRACK FASTENINGS

149. Rail-braces.—The lateral thrust of the wheels against the rails is unusually severe on curves and turnouts. This tends to overturn the rails and to spread the gage. This thrust is transmitted to the ties by the use of rail-braces on the outside of the rail. The brace fits under the rail-head and the broad base of the brace is spiked to the tie. Braces are used also on guard-rails and on shimmed track. They are not generally used on curves of small degree, particularly if the track is tie-plated. At turnouts they may be placed directly on the ties or on the ends of the slide-plates. The slide-plates frequently have cleats against which the outer edges of the braces bear. Braces may be used either with cut spikes or screw-spikes. They are made of cast iron, wrought iron, malleable iron, and pressed steel. Temporary wooden braces may be used in shimming. Cast-iron braces break easily, while those of pressed steel corrode rapidly,

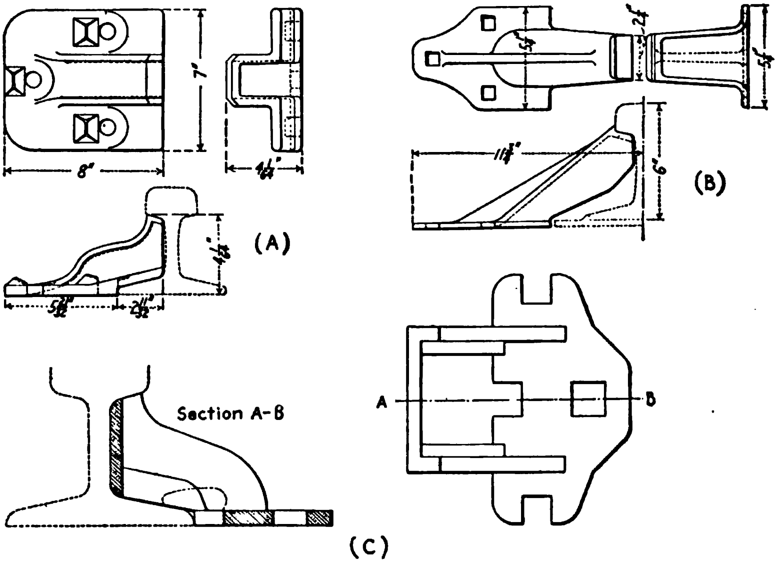
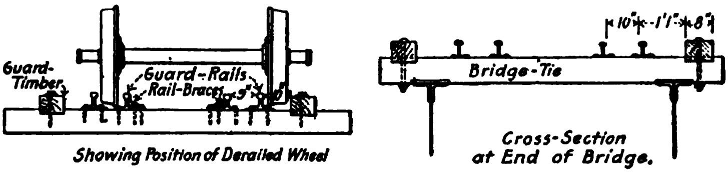


Fig. 98.—Rail-braces.

in some cases rusting away in 4 or 5 years. Several types of rail-braces are shown in Fig. 98. There is usually one central reinforcing rib, but the plate shown at (*C*) has two ribs, one at each side of the plate. The brace (*A*) is for use with screw-spikes and (*B*) is for use with tie-plates. The latter is made of pressed steel, while (*C*) is a malleable-iron brace.

Rail-braces should always be placed in pairs, one on each end of the same tie, on the outside of the rails. Different railways use a different number of braces per rail per degree of curve. In most cases braces are not used on curves of less than 3°. The practice of the Canadian Pacific Railway is to use four pairs per 33-ft. rail on curves up to 4°, increasing one pair per rail length for each additional degree of curvature until all ties carry braces. Where used they should extend from the point where the superelevation or the transition curve starts, and should extend to the same point at the end of the curve. The number required on the transition is in proportion to the superelevation.

150. Guard-rails.—A guard-rail is a longitudinal member, usually second-hand track-rails, placed inside the rail to hold the wheels in their proper position on the rails or to guide derailed wheels. In a few exceptional cases guard-rails are placed outside the track-rail. Inner guard-rails are used on bridges and trestles, in tunnels, at derailing switches, at bridge expansion-joints in the track, on sharp curves, and opposite all frogs. Guard-rails for frogs are discussed in Art. 223.


Guard-Timber
Guard-Rails
Rail-Braces
9"
10"
Showing Position of Derailed Wheel
10"
1'1"
8"
Bridge-Tie
Cross-Section at End of Bridge.

(A) P.R.R. (B) B.&O. R.R.

FIG. 99.—Spacing of guard-rails on bridges.

Guard-rails on bridges appear first to have been used on through bridges as a protection for the structure against derailed trains or cars. The protection of the train and lives of the passengers is more important than the protection of the structure. If guard-rails are a protection to through bridges by guarding derailed cars, they will give equal protection to the train on deck-structures. Hence, guard-rails should be used on all bridges and trestles as a protection for the train. On open-floor bridges, guard-timbers are usually placed outside the rails at the ends of the ties, their purpose being to properly space the ties and hold them in place. The inner guard-rails should be so spaced with relation to the track-rails that derailed wheels will strike the guard-rail without striking the guard-timber. The distance in the clear from gage of guard-rail to gage of main rail is from 8 to 10 in. for ordinary bridge guard-rails and about 2½ in. for curve guard-rails. Figure 99 shows the standard spacing of bridge guard-rails of the Pennsylvania R. R. and the Baltimore and Ohio R. R. The ends of close guard-rails on curves flare to about 10 in. in a distance of 6 ft. When guard-rails are placed more than 6 in. inside the main rails, their ends should be brought together at both ends of single-track bridges and at the facing end of double-track bridges. They should extend at least 50 ft. beyond the end of the bridge facing the direction of traffic and,

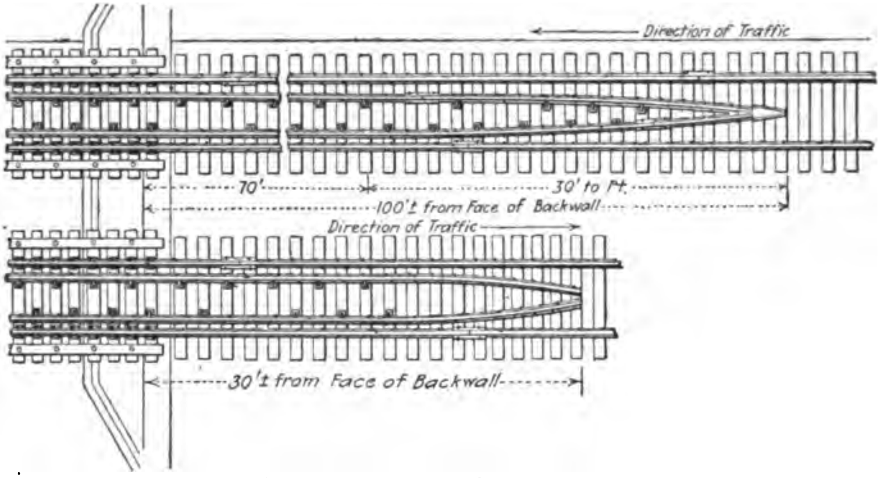


FIG. 100.—Arrangement of guard-rails at ends of bridges.

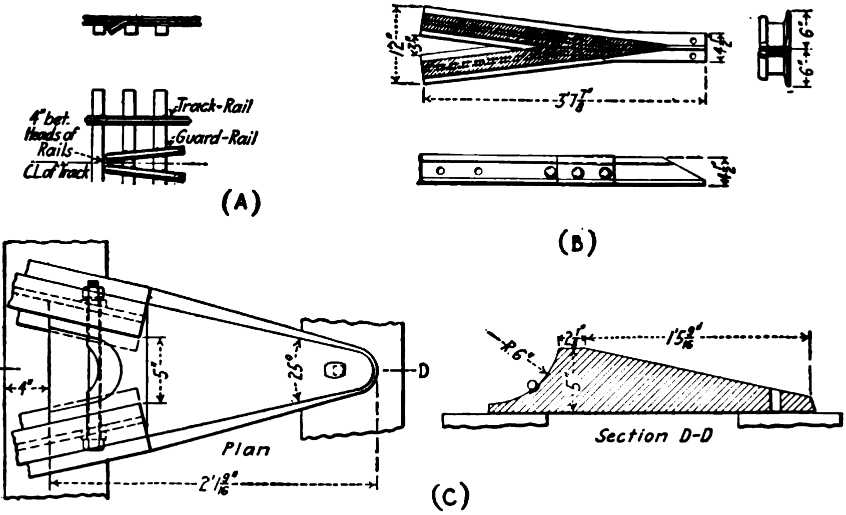


FIG. 101.—Protection for points of guard-rails.

on double track from 15 to 30 ft. beyond the leaving end of the bridge. The standard guard-rail arrangement of the Pennsylvania R. R. for bridges, trestles, and viaducts with open floors is shown in Fig. 100.

Where the ends of the guard-rails are brought together, one of the following means should be used to prevent brake rigging from catching on the exposed ends: (1) Outer ends of guard-rails bent down to clear the top of ties. (2) Ends of rails planed to tapering edges and bolted together. (3) Ends of rails bolted to and protected by a wedge-shaped casting. These three methods are illustrated in Fig. 101 at (*A*), (*B*) and (*C*). Guard-rails should be fully spliced at joints and spiked to at least every second tie, and rail-braces should be placed on every second or third tie on the track-center side. Besides the inner guard-rails on curves placed to give a flangeway of about 2½ in., an outer guard-rail or "hold-up" rail must be placed the same distance outside the inner rail of curves of 16° or over to prevent blind driving-wheels from dropping. The American Railway Engineering Association recommends the use of inner guard-rails on all open-floor and on the outside tracks of all solid-floor bridges longer than 20 ft. in main-line tracks and on similar structures in branch-line tracks where the speed of trains is 20 miles per hour or more.[1]

151. Rail-chairs.—At one time rail-chairs were extensively used with T rails on steam- and street-railway track in paved streets, to allow the ties to be placed below the bottom of the pavement. A chair of this type is shown in Fig. 70. The use of girder rails has made the rail-chair obsolete for this purpose. In some recent installations rail-chairs have been used on open track under the outer rail of curves, to provide the proper elevation in place of inclining the ties in the ballast. The height of the chair is made the same as the required superelevation and its rail-seat is inclined to give the proper cant to the rail. The inner rail is left vertical, producing a condition similar to that resulting from the use of canted tie-plates on ties inclined in the ballast. A canted rail-chair of this type is shown in Fig. 102. In some cases the rail is bolted to the chair, but usually the rail is wedged in the chair. The chairs are fastened to the ties by cut-spikes or screw-spikes.

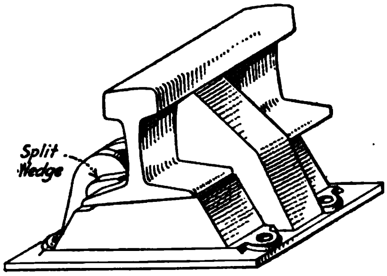


Fig. 102.—"Superior" combined rail-brace and canted rail-chair.

In England the rail-chair is the standard support for the bull-head rail. These chairs are quite heavy, weighing from 26 to 56 lb. The wear of the rails is excessive at the chairs and the bearing surface of the rail upon the chair is less than that of a T rail upon a tie. An advantage is that tie-plates are unnecessary and the chairs hold the rail uniformly to gage. The method of fastening these chairs to the ties is described in Art. 142. This type of chair, the method of fastening the rail to it, and it to the tie, are shown in Fig. 103.

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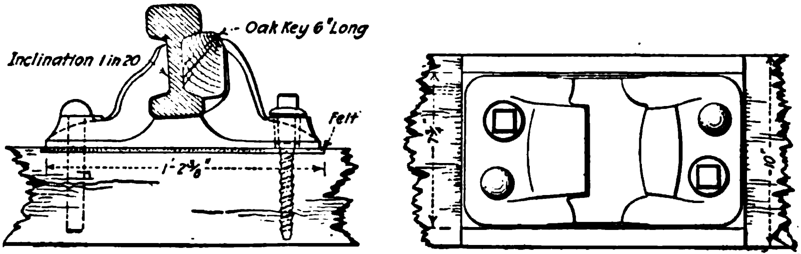
[1] Bulletin No. 169, American Railway Engineering Association

152. Shims.—A shim is a piece of wood or metal placed between two surfaces to make a tight fit. In maintenance work shims are of two kinds: (1) Expansion shims. (2) Track shims. Expansion shims are flat metal plates used to gage the expansion space between the ends of contiguous rails when laying rail. The shims are made in the different thicknesses shown in Table 12. A shim of the proper thickness is placed against the end of the rail last laid and the end of the rail being laid is pushed against the shim, without bumping, until the fit is tight enough to offer some resistance to withdrawing the shim. Each shim should be stamped with the temperature for which it is intended to be used. While laying rail the shims should be kept by the man taking the temperature readings of the rail, and those being used should be exchanged by him when warranted by temperature changes.



Cross Section Showing Chair and Fastenings Plan (Rail and Key Removed)

FIG. 103.—Cast-iron rail-chair for British Standard bull-head rail.

Track shims are flat pieces of wood varying from ⅛ to 2½ in. in thickness, from 4½ to 7 in. in width, and from 8 to 24 in. in length. For a thickness greater than 2½ in. the shims are best made long enough to extend under both rails. They are temporarily used to bring the rail to surface in track which has heaved because of frost or wet roadbed. The necessity for the use of shims is an indication of poor drainage under the heaved ties. The causes and remedy for heaving track are discussed in Art. 231. When heaving throws the track out of surface, a shim of the proper thickness to make the two rails level is inserted between the tie and rail on the low side, or under both rails if both are low in spots. Narrow shims can be used by slightly drawing the track-spikes, pinching up the rail and sliding the shim under the rail. If wide shims are used the spikes must be entirely drawn and redriven through the shim. Shims should be long enough to extend beyond the base of the rail on each side, and if wider than 5 in. they should have bored spike-holes to prevent their being split by driving the spikes through them. Shims 1½ in. or more in thickness are usually 9 to 12 in. long. Thicker shims are made longer and may have additional holes for spiking the shim to the tie. If a shim which is more than 1 in. thick is used, the track-spikes must be replaced with shimming-spikes (Fig. 89). Thin shims may be fastened to the ties with nails. Those thinner than ⅛ in. are useless. Shims should be made of the hardest local timber. Oak, maple, beech, birch, and even hemlock are used. The maximum life of a shim is about 2 years. The average cost up to a thickness of 2 in. and length of 9 in. is about ¼ ct. each. If the rail is braced, the braces will have to be removed before placing the shims and they must be replaced afterward. Either a standard brace or a temporary wooden brace consisting of a piece of 2- by 6-in. plank about 12 in. long, one end being placed against the web of the rail and the other end being spiked to the tie, should be used on all high, narrow shims.

153. Tie-bars.—Tie-bars are used to maintain the proper gage between the rails of split-switches, slip-switches and movable-point frogs, and to maintain gage between lift rails on draw-bridges, girder rails in street-railway track, and occasionally the rails on curves in steam-railway track. For switch-rails, movable-point frogs, and lift rails, they must be designed to take both tension and compression. Where used only to maintain gage they need take only tension. The ends may be bent up to fit against the inside of the rail-web, to which they are bolted, or they may be formed into a threaded round rod which extends through the web and holds the rail by nuts on each side of the web, or they may hook over the base of the rail.

CHAPTER XI

STRESSES IN THE TRACK

154. Moving Loads Carried by the Track.—It is an easy matter to calculate the weights of engines and cars and to determine their static axle loads, but the actual pressure received by the track from the wheels, particularly the drive-wheels, of a moving train is very different from the static load and can be computed only approximately.

Considering a locomotive, the increase of the dynamic load over the static load, which we will call the "dynamic augment," is due to several causes, the most important of which are:

1. The effect of incorrect counterbalance.
2. The angularity of the main rod.
3. Irregularities existing in the track.
4. Irregularities in the rolling-stock.
5. The rocking and swaying of the locomotive on its springs.
6. The effect of the velocity of the wheel load.

The counterbalance is a concentrated weight attached to the spokes of a drive-wheel to counteract the revolving weights of the crank-pin and main or side rod, and about two-thirds of the reciprocating weights of the cross-head, piston and piston-rod. The main or connecting rod transmits the motion of the piston and piston-rod to the drive-wheels. It is pivoted at one end to the cross-head and at the other end, by means of the main crank-pin, to the main drive-wheel. By angularity of main rod is meant the greatest angle made by this rod to the horizontal at any time during one revolution of the drive-wheel. The maximum angle occurs when the main crank-pin is vertically above or below the axle of the wheel.

155. The Effect of Incorrect Counterbalance and Angularity of Main Rod.—By actually weighing the counterbalance and moving parts of many locomotives, it has been found that the weight of the counterbalance is often too much or too little by amounts varying from a few pounds up to several hundred pounds. The most exceptional case on record doubtless is that of the Canadian Pacific Railway locomotive which was found to have an excess of counterbalance in the main drivers of about 1000 lb. In 1908, a series of badly indented rails were observed on this railway, both rails for a distance of about 2 miles being sharply indented at regular intervals. The distance between damaged spots was measured and was found to correspond to the diameter of the drivers of a locomotive that had made a very fast run over the track the previous day. The drivers of this engine were taken out and weighed and the condition mentioned above was discovered.

The pressure of the wheel on the rail will vary when incorrect counterbalance exists. It can be considered as equal to the static wheel pressure plus or minus the vertical action of the unbalanced weight. This is illustrated by (*A*), Fig. 104, in which *AK* represents the distance traveled in one revolution of the wheel, *AB* the static pressure of the wheel, *BC* a horizontal line corresponding to a uniform moving pressure equal to the static pressure, and *AHKE* a curve whose ordinate at any point equals the vertical pressure due to incorrect counterbalance. The actual pressure would be the algebraic sum of the two pressures and at any point would be the ordinate to the curve *BFG*.

For high speeds and excessive overbalance, the vertical force of the overbalance acting upward may exceed the weight on the wheel, giving a negative pressure or a force tending to lift the wheel from the rail. Such a condition is shown at (*B*), where that part of the curve below *AD* represents an actual upward force *PT* which occurs when the counterbalance is vertically above the axle for overbalance and vertically below the axle for underbalance.[1]

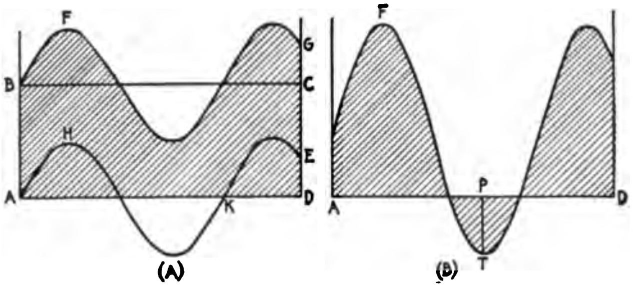


FIG. 104.—Diagram showing the effect of incorrect counterbalance.

Even with perfectly balanced wheels the angularity of the main rod always causes an increase of pressure on the main driver. This, of course, is equaled by a corresponding upward pressure on the piston guide so that the weight on the truck is reduced by an amount equal to that by which the weight on the driver is increased. Knowing the amount of incorrect counterbalance, it is possible to compute the combined effect of incorrect counterbalance and angularity of main rod.[2]

Computations of this kind made for heavy modern passenger-engines of the 4-4-2, 4-6-2, and 4-6-0 types for speeds up to 60 miles per hour gave the following results: For a 4-4-2 locomotive having axle loads of 55,000 lb. on the main drivers and 52,000 lb. on the secondary drivers, the excess pressures per wheel were 12,000 lb. and 9000 lb., respectively. For a 4–6–2 locomotive having axle loads of 60,000 lb. on the main drivers and 56,000 lb. on the secondary drivers, the excess pressures per wheel were 10,000 lb. and 7000 lb., respectively. For a 4–6–0 locomotive having

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[1] For a mathematical solution of this problem see "The Hammer Blow from Incorrect Counterbalance," by H. H. Vaughan, American Engineer and Railroad Journal, Feb., 1909.

[2] For solution see page 38, Steel Rails, by W. H. Sellew,

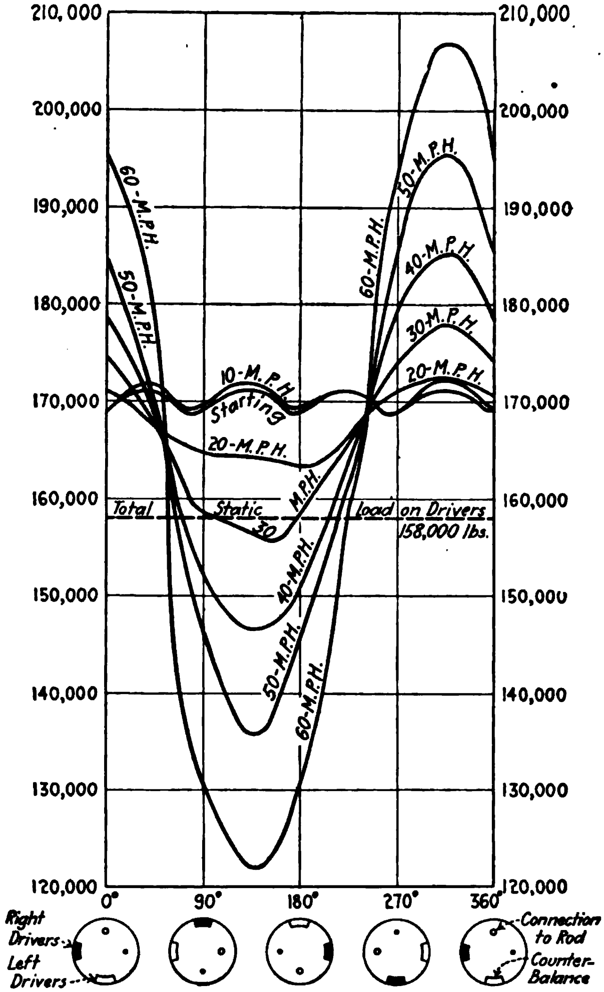

FIG. 105.—Diagram of rail pressure, Mogul-type locomotive.

axle loads of 55,000 and 52,000 lb. on the main and secondary drivers, respectively, the excess pressures per wheel were 11,000 and 10,000 lb., respectively. The greatest excess pressure of any of the three types was for the main driver of the 4–4–2 type, which was 12,000 lb. For high speeds the excess pressure for freight-locomotives is greater than for passenger-locomotives; but as the working speeds of the former are much below those of the latter the excess pressure for freight-locomotives should be computed for lower speeds. Computations made for heavy modern freight-locomotives of the 2–6–0 and 2–8–0 types, the former having axle loads of 54,000 lb. for the main drivers and 53,000 lb. for the secondary drivers, and the latter having axle loads of 54,000 lb. and 50,000 lb. on the main and secondary drivers, show that for speeds up to 40 miles per hour the greatest excess pressure occurs with the 2–6–0 type, and is 10,000 lb. for each of the main drivers and 5000 lb. for each of the secondary drivers. Fig. 105 is a diagram showing the sum of pressures of all three sets of drivers of a locomotive of the 2–6–0 type for different speeds and different positions of the counterbalance.

The excess pressure due to incorrect counterbalance and angularity of main rod is not a direct function of the axle load and should be determined for each type of locomotive.

156. The Effect of Irregularities in the Track.—No railway-track has an absolutely smooth surface. Even in the very best of track some ties are more lightly tamped than others. The action of heavy trains passing over the track is to develop low spots in the track at the lightly tamped places. Therefore, the riding surface of each rail is a series of sags and summits whose heights vary from a fraction of an inch to 2 or 3 in., depending upon the care given to the track. On account of the stiffness of the rails and their continuity, these irregularities, even in very rough track, are really a series of very short vertical curves. When a wheel rolling along the rail passes over a summit of one of these irregularities, the velocity of the train produces a tendency for the wheel to leave the rail. As the wheel follows the vertical curve of a sag, a centrifugal force is developed in the load, causing an imposed pressure upon the wheel. Let C = centrifugal force in lb., M = mass, W = load on wheel in lb., g = acceleration of gravity, R = radius of vertical curve of irregularity in track in feet, and v = velocity of train in feet per second. Then this force is $C = \frac{Mv^2}{R}$, and acts away from the center of gravity and against the rail. Investigation has shown that for small irregularities the radius of vertical curvature is close to 5280 ft. For a speed of 60 miles per hour and a wheel load of 30,000 lb.,

$$M = \frac{W}{g}, \text{ and } C = \frac{5280^2 \times 60^2 \times 30{,}000}{5280 \times 32.2 \times 3600^2} = 1366 \text{ lb.}$$

It should be noticed that unlike the excess pressure discussed in Art. 155, this pressure is proportional to the weight on the wheel. The sharper are the irregularities, the shorter will be the radii of the vertical curves and the greater the centrifugal force C. For rough track, R may be as short as 1000 feet, which would give C = 7215 lb. for a speed of 60 miles per hour. A speed of 60 miles per hour would be excessive for such a rough track, and 40 miles per hour would more nearly represent actual conditions. For such a speed C would equal 3243 lb. If we allow 4000 lb. for this imposed pressure due to irregularities of track, the factor of safety would undoubtedly be sufficient for all practical cases. In computing the excess pressure the wheel load was used, and this pressure can now be expressed as a percentage of the wheel load. Excess pressure equals $\frac{4000}{30,000}$ = 13 per cent. of the weight on the wheel.[1]

157. The Effect of Irregularities in the Rolling-stock.—Flat spots on the treads of car- and locomotive-wheels are more injurious to the track than are any of the other common irregularities in the rolling-stock. At some time the reader may have observed the progress of a street-car having a flat spot on one of its wheels. In such a case the noise of the blow which the rail receives at regular intervals from the wheel is quite noticeable. It is hard to determine what damage, if any, is done by small flat spots, but when the flat spot is several inches long the track, and especially the rail, may be very seriously damaged. The following are a few of the phenomenal cases of this kind: During the year 1900 a locomotive of the Chicago, Milwaukee and St. Paul broke some 27 new 85-lb. rails in one week. On examination of the locomotive one drive-wheel was found to have a flat spot 32 in. long. In the Railway Age Gazette of March 16, 1910, a report was given of the breakage of 200 85-lb. rails in a distance of 14 miles by a flat spot which had grown to a length of 8 in. and a maximum depth of 3/8 in. During the months of January and February, 1912, some extremely cold weather was experienced. This weather brought a deluge of broken rails. The failure of many of these was attributed to the presence of many flat wheels which resulted from shelling-out of the wheel-tread due to the extreme cold. Many chilled-steel car-wheels are now in use, yet it is a fact that in their manufacture but few of them are evenly chilled. This not only weakens the wheel but also produces a lack of roundness which causes pounding on the rail. The following are some of the recorded failures in the winter of 1912: During the month of January, in Minnesota, a flat spot 4 in. long on a rolled-steel wheel of a passenger-engine broke nine 80-lb. rails in 3 miles. On January 7, at Savanna, Ill., a flat spot 5½ in. long on a steel-tired wheel in passenger service broke 150 rails. On January 14, in South Dakota, two steel wheels with flat spots, on different trucks of a dining-car, broke 500 rails. During February, in Ohio, a shelled-out steel-tired wheel having a flat spot 9 in. long at end of run broke 960 rails in 200 miles.

As mentioned before, a lack of roundness is often observed in chilled-steel wheels. Tests conducted by the Lake Shore and Michigan Southern

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[1] Steel Rails, by W. H. Sellew.

Ry. prior to 1910 on carefully hand-turned chilled-steel wheels showed variations as great as 0.056 in. from the true round.

Several devices have been invented for actually testing the effect upon the rail of flat spots. The American Railway Engineering Association also conducted a series of tests with a car having two flat wheels. The results showed a pressure of from 1000 to 2000 lb. more on the springs of the trucks having flat wheels than on the other trucks.

Several methods have been suggested by which the actual blow received by the rail from a flat wheel can be theoretically determined. The results are somewhat different in each case according to the assumption made in the mathematical solution. Most theoretical results undoubtedly give excessively large values for high speeds. The following solution is believed to give results agreeing with those actually observed.[1] The solution is based upon the assumption that the weight carried by each wheel below the springs is connected at the center of the axle and that this weight is pressed down by a force equal to the weight supported by each wheel above the springs.

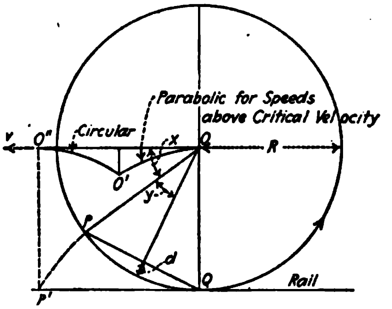

FIG. 106.—Flat spots in car-wheels.

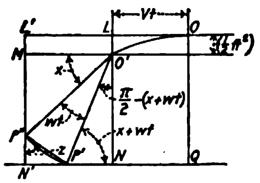

FIG. 107.—Flat spots in car-wheels.

Referring to Figs. 106 and 107:

Let R = radius of wheel in feet.

PQ = flat spot of length l and depth d, in feet.

v = velocity of center of wheel parallel to rails = velocity of train in feet per second.

v_s = striking velocity of flat spot in feet per second.

v_l = velocity in feet per second above which front edge of flat spot leaves rail, or limiting velocity.

v_r = velocity in feet per second of point P due to rotation of wheel about its center.

P = constant pressure in pounds received by wheel from springs.

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[1] Effect of Flat Wheels on Rails, by H. H. Vaughan, American Engineer and Railroad Journal, Dec., 1908.

W = weight of wheel in pounds.
f = downward acceleration of wheel.
w = angular velocity of wheel $= \frac{v}{R}$.

In Fig. 106 the forward edge of the flat spot is in contact with the rail and the wheel is pivoting about the point Q. The centripetal force at this instant is $\frac{v^2}{R}$ and acts along QO or upward, and the downward acceleration is $\frac{P+W}{W}g = f$. As long as the downward acceleration is greater than the upward acceleration point Q will remain in contact with the rail until QP comes in contact with the rail, at which instant the flat spot delivers a blow to the rail. As soon as $\frac{v^2}{R} > f$ the point Q will leave the rail. Therefore, point Q will be in contact with the rail for all velocities up to the limiting velocity $v_l = \sqrt{fR}$ (157a)
For any velocity up to v_l the downward velocity of point P is proportional to the velocity v, or

$$\frac{v_s}{v} = \frac{l}{R}$$

$$v_s = \frac{vl}{R} \tag{157b}$$

When the limiting speed is reached,

$$v_s = \frac{v_e l}{R} = l\sqrt{\frac{f}{R}} \tag{157c}$$

In Fig. 107 the following edge of the flat spot is shown at the instant of contact with the rail.

After the limiting velocity is reached the downward acceleration of the wheel is the same as before and equals f, but the motion of the point P is now made up of two distinct motions: (a) translation, and (b) rotation. Let t = time in seconds from when Q leaves the rail to when P strikes the rail. During the time t, the wheel as a whole moves horizontally forward a distance vt ft. (Fig. 107), and vertically downward a distance $\frac{1}{2}ft^2$ ft. During this interval the wheel rotates about its center through an angle wt and P moves from P'' down to the rail at P'.

In Fig. 107,

$$P''P' = 2R \sin \frac{wt}{2}$$

$$z = x + \frac{wt}{2}$$

$$P''N' = P''P' \cos z$$

$$L'M = \tfrac{1}{2}ft^2$$

$$MP'' = R \sin x$$

$$R = OQ = L'M + MP'' + P''N$$

Substituting,

$$R = \tfrac{1}{2}ft^2 + R\sin x + 2R\sin\frac{wt}{2}\cos\left(x + \frac{wt}{2}\right)$$

$$= \tfrac{1}{2}ft^2 + R\sin\left(x + \frac{wt}{2}\right) \qquad (157d)$$

The distance between points of departure and strike is,

$$\begin{aligned} QP' &= QN + NP' \\ QN &= vt,\ NP' = R\cos(x + wt) \\ QP' &= vt + R\cos(x + wt) \end{aligned}$$

At the instant of striking, the vertical downward velocity of the wheel as a whole $= ft$, in feet per second. The velocity of the point P' is v_r and is perpendicular to the radius $O'P'$. The vertical component $= v_r \cos(x + wt)$.

Therefore,

$$v_s = ft + v_r\cos(x + wt) \qquad (157e)$$

$$v_r = Rw$$

then,

$$v_s = ft + Rw\sin\left(\frac{\pi}{2} - x - wt\right)$$

Since $\left(\frac{\pi}{2} - x - wt\right)$ is very small the angle may be substituted for the sine, and

$$v_s = t(f - Rw^2) + Rw\left(\frac{\pi}{2} - x\right) \qquad (157f)$$

From 157*d*,

$$R = \tfrac{1}{2}ft^2 + R\cos\left(\frac{\pi}{2} - x - wt\right)$$

or,

$$R = \tfrac{1}{2}ft^2 + R\left[1 - \left(\frac{\frac{\pi}{2} - x - wt}{2}\right)^2\right]$$

since $\left(\frac{\pi}{2} - x - wt\right)$ is very small.

$$t\left(w + \sqrt{\frac{f}{R}}\right) = \left(\frac{\pi}{2} - x\right)$$

$$t = \frac{\frac{\pi}{2} - x}{w + \sqrt{\frac{f}{R}}}$$

Substituting in 157*f*,

$$v_s = \left(\frac{\pi}{2} - x\right)\left[\frac{f - Rw^2}{w + \sqrt{\frac{f}{R}}} + Rw\right] = \left(\frac{\pi}{2} - x\right)\left[\frac{f + Rw\sqrt{\frac{f}{R}}}{w + \sqrt{\frac{f}{R}}}\right] \qquad (157g)$$

Multiplying the numerator and denominator of the quantity in the bracket by $\sqrt{fR}$ and then dividing them by fR, reducing to a common denominator and simplifying, the bracket reduces to $\sqrt{fR}$.

In Fig. 106,

$$QP = l = 2R \sin y$$

but

$$y = \left(\frac{\pi}{2} - x\right)$$

$$l = 2R \sin \left(\frac{\pi}{2} - x\right)$$

or,

$$\left(\frac{\pi}{2} - x\right) = 2 \sin^{-1}\left(\frac{l}{2R}\right)$$

Substituting in 157*g*,

$$v_s = 2 \sin^{-1}\left(\frac{l}{2R}\right)\sqrt{fR} \qquad (157h)$$

For small flat spots, $\sin^{-1}\left(\frac{l}{2R}\right) = \frac{l}{2R}$ approximately.

Therefore, when the velocity of the train is greater than v_l,

$$v_s = 2\frac{l}{2R}\sqrt{fR} = l\sqrt{\frac{f}{R}} \qquad (157i)$$

which is the same value as found in 157*c*. This shows that after the limiting velocity is reached the striking velocity is independent of the velocity of the train and is constant for any given wheel and flat spot; and for any given wheel, v_s varies directly with the length of flat spot.

Let M = mass and K = kinetic energy. Then the kinetic energy of the blow struck the rail is

$$K = \tfrac{1}{2}Mv_s^2 \qquad (157j)$$

$$M = \frac{P + W}{g} \qquad (157k)$$

Hence,

$$K = \frac{(P + W)}{2g} v_s^2 \qquad (157l)$$

For a 33-in. car-wheel weighing 1600 lb. and receiving a weight of 14,400 lb. from the springs, and a flat spot 6 in. long, the striking velocity is 7.6 ft. per second. The blow would be

$$K = \frac{16{,}000 \times 7.6^2}{2 \times 32.2} = 14{,}350 \text{ ft.-lb.}$$

and the limiting velocity would be about 21 ft. per second, or 14.5 miles per hour and is independent of the length of flat spot.

The present rules of the Master Car Builders' Association limit the allowable length of flat spots in wheels to 2½ in.

158. Rocking of the Locomotive on Its Springs.—During 1906, tests were conducted on a locomotive of the Boston and Maine Railroad to determine the live load on the springs under actual running conditions. By means of an automatic recording apparatus a maximum deflection of the spring of 0.34 in. was recorded. The set in the spring due to the dead load of the locomotive was marked. The spring was then removed from the locomotive and placed in a testing machine. The load was gradually applied until the deflection due to the dead load was obtained. A load of 3500 lb. was then required to produce an additional deflection of 0.34 in. The total load on the spring was 17,700 lb., giving an average load of 15,950 lb. acting through 0.34 in. The total work would be 15,950 × 0.34 = 5423 in.-lb. The average live load on the spring was 1750 lb. or 12.3 per cent. more than the static load. Therefore, the dynamic augment due to the action of the springs can be taken as approximately 12 per cent. of the static wheel load.

159. Effect of Velocity of the Wheel Load.—A wheel of a train standing on a track depresses the track into a concave vertical curve. In the case of a bridge, where the supports are rigid, the structure deflects under the load so that if the track was originally level the deflection of the structure between the supports produces a vertical curve over which the center of gravity of the load travels. A centrifugal force is thus developed which produces impact. However, when not on a bridge the track is depressed as the train moves over it so that the center of gravity of the load tends to follow a straight line, producing no centrifugal force.

The effect of the velocity of the wheel load must not be confused with the effect of irregularities in the track. As has already been shown, irregularities in the track do produce a certain dynamic augment, while the effect of the velocity of the wheel load is neutralized by the elasticity of the track. On bridges, unless the track is laid in ballast, which is seldom the case on long bridges, the conditions may be reversed, since the track is very rigid and the surface uniform, so that a much greater impact results from the velocity of the wheel load than from irregularities in the track. On open track the effect of the velocity of the wheel load may be neglected.

160. Impact.—All of the causes of dynamic augment enumerated in Art. 154 and briefly described subsequently combine to exert upon the track the force called impact. Impact is defined as being the dynamic effect of a live load, and depends upon the conditions under which the live load is applied. The investigation in the last six Articles of the different causes of impact shows that such is really the case.

In the design of a bridge it is very important that the actual live load stresses be increased by a certain amount to take account of the stresses due to impact. As in the case of the members of a bridge, so are the component parts of the ordinary track subject to the stresses of impact, though probably to a somewhat less degree due to the elasticity of the track.

Examining what actually takes place in the track when impact occurs, it is seen that under absolutely normal conditions of perfect track and perfectly balanced wheels there is no impact and a force "F" acts between the wheel and the rail. When conditions are not normal and impact occurs this force F is increased by a force F'. As the force is now $F + F'$ instead of F, a change is produced in the relative velocities of the wheel and track. Relatively speaking, the tendency now is for the wheel to move slower than the track, and the result is that the track receives a shock from the wheel. The average value of this force F' is equal to the change in momentum produced by its action divided by the time required to produce this change, or $F' = \frac{M(v - v_1)}{(t - t_1)}$, where M = mass, v and v_1 = velocity in feet per second, t and t_1 = time in seconds.[1] At low speeds the force F' is taken up by the elasticity of the track, the entire track being compressed. The time interval $t - t_1$ is very small and at high speeds is not sufficient to allow the force F' to depress the track to the limit of its elasticity. Also, the heavier and stiffer the rail the less the track as a whole can be depressed and the more the force F' is borne by the rail. It is very probable that at times this force exceeds the crushing strength of the metal in the upper surface of the rail-head.

During the years 1907 to 1909 inclusive, a committee of the American Railway Engineering Association conducted elaborate field experiments to determine the stress in bridge members due to impact. Those of the committee's conclusions which have a bearing on track construction and maintenance are given below:

1. With the track in good condition the chief cause of impact was found to be the unbalanced drivers of the locomotive.
2. When the rate of rotation of the locomotive drive-wheels corresponds to the rate of vibration of the loaded structure cumulative vibration is caused which is the principal factor of producing impact in long spans. The speed of the train which produces this cumulative vibration is called the *critical speed.* A speed either in excess of or below the critical speed will cause less severe vibrations than those caused at or near the critical speed.
3. The longer the span length the slower is the critical speed; therefore, the maximum impact on long spans will occur at slower speeds than on short spans.
4. For short spans such that the critical speed is not reached by the moving train, the impact percentage tends to be constant so far as the effect of the counterbalance is concerned; but the effect of rough track and wheels becomes of greater importance for such spans.
5. In general, the results at 10 miles per hour may be considered as practically equal to static stresses.
6. The effect of differences of design was most noticeable with respect to

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[1] Steel Rails, by W. H. Sellew, page 68.

differences in the floor system. An elastic floor such as furnished by long ties supported on widely spaced stringers or a ballasted floor gave the smoothest stress curves.

7. For smooth track and balanced loads the impact due to the rapid application of load was of no practical importance.

8. The impact caused by balanced compound and electric locomotives was very small and the vibrations caused under the loads were not cumulative.

9. The effect of rough and flat wheels was plainly noticeable on floor beams but not on the truss members.

10. The maximum impact percentage as determined by these tests is closely given by the formula,

$$I = \frac{100}{1 + \frac{L^2}{20,000}}$$

where I = impact percentage and L = length of span in feet.

161. Total Dynamic Augment.—It has now been shown that the maximum pressure on the track, not considering bridges, is produced by (*a*) the static load, (*b*) the excess pressure due to incorrect counterbalance and angularity of main rod, (*c*) irregularities of track and (*d*) rocking on the springs, (*e*) and that in some cases the sum of these may be increased by imperfect wheels. Causes (1), (2), (3) and (5) of dynamic augment, given in Art. 154, can now be added to the static wheel load in order to get the total wheel pressure on the rail exerted by a moving locomotive. From Arts. 156 and 158 it is seen that irregularities of track, combined with the action of the springs, cause an imposed pressure equal to 25 per cent. of the static wheel load of heavy locomotives. Therefore, for heavy locomotives, which are considered as those having wheel loads of 25,000 lb. or over, the total dynamic augment is as follows:

PASSENGER-LOCOMOTIVES.—For each truck-wheel: dynamic augment = 25 per cent. of static wheel load.

For each main driver: dynamic augment = 25 per cent. of static wheel load plus 12,000 lb.

For each secondary driver: dynamic augment = 25 per cent. of static wheel load plus 9000 lb.

FREIGHT-LOCOMOTIVES.—For each truck-wheel: dynamic augment = 25 per cent. of static wheel load.

For each main driver: dynamic augment = 25 per cent. of static wheel load plus 10,000 lb.

For each secondary driver: dynamic augment = 25 per cent. of static wheel load plus 5000 lb.

If the amount of the irregularities of the track can be determined, the 25 per cent. in the above list should be changed to 12 per cent. and then the actual computed pressure due to track irregularities should be added in the place of the 13 per cent. used above. The dynamic augment

100-lb. rail, under a similar engine at a speed of 5 miles per hour backing up light, was 11,810 lb. per square inch under the trailing wheel. The maximum tensile stress due to this engine pulling its train of nine cars at a speed of 16 miles per hour was 22,911 lb. per square inch under the front driver. The maximum positive bending moment under this driver was 380,323 in.-lb. The maximum negative bending moment of 58,814 in.-lb. was between this driver and the rear truck-wheel.

The elasticity of the metal in the wheel-tread and top of rail-head results in the contact of the wheel with the rail being a small area, rather than the theoretical point or line. The area of the contact surface is always small but increases with the elasticity of the metals and the weight on the wheel. It varies from 0.1 to 0.5 sq. in. according to the above conditions. Hence it is seen that the metal in the top of the rail-head may be stressed considerably beyond its elastic limit. A wheel load of 25,000 lb. with a dynamic augment of 40 to 60 per cent. and a contact spot of 0.5 sq. in. would produce a compressive stress of 87,500 to 100,000 lb. per square inch in the metal of the contact spot. However, the flow of this metal is restricted by the surrounding metal so that in all but extreme cases the metal is not injured.

If the joints are tightly bolted, sudden changes in temperature may produce a tensile or compressive stress in all parts of the rail of from 3000 to 10,000 lb. per square inch (see Art. 118).

165. Stresses in the Track Fastenings.—Laboratory tests made on rail-joints show that the stiffness of modern splice-bar joints compared to that of rail is from about 20 per cent., for the plain angle-bar, to slightly over 100 per cent. for a few of the patented deep-flange or base-supporting joints. There are so many unknowns that a rigid mathematical solution is impossible.[1]

In 1907 the Pennsylvania Railroad conducted tests on a section of track on the West Jersey and Seashore Railroad to determine the lateral horizontal pressure on the outer rail of curves generated by different classes of locomotives.[2] In arriving at the stresses in the fastenings resulting from the observed horizontal pressures, the following assumptions and computations were made: About 4¾ in. of a 6-in. spike extends into a tie, tie-plates being used. The horizontal force transmitted from the rail to the spike is distributed over the wood back of the spike in such a way that the pressure is a maximum where the spike enters the wood and decreases uniformly to zero at the point of the spike. Neglecting the action of the pressure on the inside of the spike near the bottom, the resultant pressure on the wood back of the spike acts at a distance below the top of spike equal to one-third the penetration of the spike.

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[1] For a proposed mathematical solution see "The Computation of Stresses in Angle-bars," by P. M. LaBach, Bulletin 167, American Railway Engineering Association.

[2] Bulletin 104, American Railway Engineering and Maintenance of Way Association.

Let f_c = the maximum crushing stress per square inch in the wood; then for a ⅝-in. spike, $\frac{f_c \times 4.75}{2} \times \frac{5}{8} = P$, or $f_c = 0.674P$. Tests have shown the ultimate shearing strength of a ⅝-in. spike to be about 19,000 lb. Substituting this value for P, f_c = 12,800 lb. This means that before a spike will shear off, the wood back of the spike at the top must stand a crushing stress of 12,800 lb. per square inch. The average maximum crushing strength endwise of the grain in the case of the best hardwoods is only about 4500 lb. per square inch. Hence the wood will crush before the spike shears off. The computed results of the tests showed that the maximum thrust which was likely to occur under practical conditions occurred at the outer wheel of the forward driver of a passenger-locomotive of the Atlantic type at 70 miles per hour on a 4° curve and having 56,750 lb. on that axle. This thrust is resisted by the friction between the base of the rail and the tie-plate, and shearing stress in the spikes. The resulting shearing stress in the spikes was computed to be 13,180 lb.

The exact distribution of the outward thrust cannot be accurately determined. A stiff rail undoubtedly distributes it to at least three ties. If there is one spike on the outside of the rail at each tie the shearing stress at each spike would be 4393 lb., while the strength of the spike is about 19,000 lb.

166. Stresses in the Tie.—The three most important elements contributing to the failure of a tie are: (1) compression endwise of the fibers, received from the spikes; (2) compression across the grain at the rail-seat; (3) breaking of the tie due to too great a bending moment.

Using the formula for f_c given in the preceding article and letting P = 4393 lb., which is the value found above for the shearing stress at each spike, f_c = 2960 lb. per square inch. This is less than the ultimate crushing strength of all but very soft woods, but is considerably in excess of the safe allowable working unit stresses given in Table 14, which are those recommended by the Association of Railway Superintendents of Bridges and Buildings. If a tie-plate is used, the spikes on the inside of the rail assist in resisting the thrust. If the rail is spiked at each tie with one spike on the outside and two on the inside, assuming the thrust to be taken equally by the three, the maximum unit fiber stress in the wood will be 987 lb., a safe value for all woods.

The percentage of the vertical load carried by a tie depends upon the stiffness of the rail and the relative supporting power of several adjacent ties. The damage to the tie at the rail-seat is due more to the sawing of the rail across the tie than to direct compression. The width of a

90-lb. A.R.A.-A rail is 5⅛ in. From Table 14, a long-leaf yellow-pine tie 9 in. wide could carry a load of 16,144 lb. from this rail without a tie-plate, while a spruce tie of the same size could carry but 9205 lb. A long-leaf yellow-pine tie with a 7-in. by 9-in. tie-plate could carry 22,050 lb.

TABLE 14.—SAFE ALLOWABLE WORKING UNIT STRESSES IN POUNDS PER SQUARE INCH FOR TIMBER

	1	2	3	4	5	
	Kind of wood	Tension, with the grain	Compression endwise of the grain	Compression across the grain	Extreme fiber stress for bending	
	Factor of safety	10	5	4	6	
1	White oak	1200	1400	500	1200	
2	Long-leaf yellow pine	1200	1400	350	1200	
3	Short-leaf yellow pine	900	1100	250	1000	
4	Douglas fir	800	1200	200	800	(Average 750)
5	Spruce and eastern fir	800	1200	200	700	
6	Cypress	600	1000	200	800	
7	Cedar	700	1100	200	700	
8	Redwood	700	....	150	750	

The conditions of a tie in the ballast are such that the tie is not strictly a simple beam, nor a constrained beam, nor a beam with ends overhanging the supports. The condition most nearly represented appears to be that of a beam with equal lengths overhanging both supports. Referring to Fig. 108, imagine the track to be turned over so that the tie acts as a beam resting on two supports, the rails, and carrying a uniform load, the ballast. The assumption that the ballast acts as a uniform load is not strictly true. A tie is always tamped lightly at the middle of the track and solidly for several inches on each side of the rails. Hence the pressure of the ballast against the bottom of the tie is not uniform along the length of the tie. As the exact conditions are indeterminate and are not the same under any two ties, the above assumption is at least as nearly correct as any other would be.

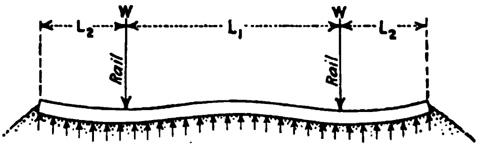

FIG. 108.—Exaggerated condition of tie under load.

Let L = length of the tie in inches.
L_1 = the distance between supports, that is, the distance from center to center of rails.
L_2 = the length of overhanging ends, or distance from center of rail to end of tie.

Then,
$$L = L_1 + 2L_2 \tag{166a}$$

Let w = uniform load (pressure on ballast) per linear inch.
W = the load the tie receives from each rail, or the reaction at each support.

Then,
$$W = \frac{wL}{2} \tag{166b}$$

Let M_c = maximum bending moment at the center.
M_s = maximum bending moment at the support.
M = maximum bending moment at any point in the tie.

Then,
$$M_c = w\left(\tfrac{1}{8}L_1^2 - \tfrac{1}{2}L_2^2\right) \tag{166c}$$
$$M_s = \tfrac{1}{2}wL_2^2 \tag{166d}$$
$$W = \frac{wL}{2} = \frac{w}{2}(L_1 + 2L_2) \tag{166e}$$

From c,
$$\begin{aligned} M_c &= \frac{w}{8}(L_1 + 2L_2)(L_1 - 2L_2) \\ &= \frac{W}{4}(L_1 - 2L_2) \end{aligned} \tag{166f}$$
$$M_s = \frac{L_2^2}{(L_1 + 2L_2)}W = \frac{L_2^2}{L}W \tag{166g}$$

For a tie 8 ft. 6 in. long and a 100-lb. R.E. rail, $L_1 = 59.2$ in. and $L_2 = 21.4$ in. Substituting these values in Eqs. f and g,
$$M_c = \frac{W}{4}(59.2 - 42.8) = 4.1W \tag{166h}$$
$$M_s = \frac{21.4^2}{102}W = 4.5\,W \tag{166i}$$

Let f = extreme unit fiber stress in bending.
y = distance of extreme fiber from neutral axis.
I = moment of inertia of section with reference to neutral axis.
b = breadth of tie.
d = depth of tie.

Then,
$$M = \frac{If}{y} = \tfrac{1}{6}\,bd^2f \tag{166j}$$

For an 8-ft. 6-in. tie, from Eq. i,
$$M = M_s = 4.5\,W = \tfrac{1}{6}bd^2f$$
$$W = \frac{bd^2f}{27} \tag{166k}$$

Substituting in Eq. *k*, the allowable load applied at each rail on a 7-in. by 9-in. by 8-ft. 6-in. white-oak or long-leaf yellow-pine tie is 19,600 lb., and for a tie of inferior wood, using an average value of 750 lb. for f, it is 12,250 lb.

For an 8-ft. tie, $L = 96$ in., $L_1 = 59.2$ in., and $L_2 = 18.4$ in. Following the same reasoning as before,

$$M_c = 5.6W$$
$$M_s = 3.6W$$
$$M = M_c = 5.6W = \tfrac{1}{6}bd^2f$$
$$W = \frac{bd^2f}{33.6} \tag{166l}$$

From Eq. *l*, the allowable load applied at each rail on a 7-in. by 9-in. by 8-ft. white-oak tie is 15,750 lb., and for a tie of inferior wood, 9840 lb. Hence it is seen that for an 8-ft. tie the maximum bending moment is at the center, and that in this respect the strength of the 8-ft. 6-in. tie is 24 per cent. greater than that of the 8-ft. tie.

167. Pressure on the Ballast.—From Eq. 166*b*,

$$W = \frac{wL}{2}$$

where w is the load per linear inch.

Let P = the safe bearing power in tons per square foot of ballast.

Then,

$$P = \frac{144}{b}w$$

or,

$$w = \frac{bP}{144} \tag{167a}$$

$$W = \frac{bP}{144} \times \frac{L}{2} = \frac{bPL}{288} \tag{167b}$$

For an 8-ft. 6-in. tie, this gives

$$W \text{ (in tons)} = \frac{bP}{2.8} \tag{167c}$$

And for an 8-ft. tie,

$$W = \frac{bP}{3} \tag{167d}$$

From Table 15, the maximum safe bearing power of broken stone or gravel ballast is 3 tons per square foot. From Eqs. *c* and *d*, the safe load which the ballast under a 7-in. by 9-in. tie could carry from each rail is

$$W = \frac{bP}{2.8} = \frac{9 \times 3 \times 2000}{2.8} = 19{,}300 \text{ lb. for an 8-ft. 6-in. tie,}$$

or

$$W = \frac{bP}{3} = 18{,}000 \text{ lb. for an 8-ft. tie.}$$

168. Pressure on the Subgrade.—From the result of a series of experiments conducted many years ago in Germany, and experiments recently conducted on the Pennsylvania Railroad giving similar results, Mr. T. H. Johnson proposes the following method for computing the bearing on the subgrade.[1] Referring to Fig. 109, the conditions for gravel ballast are represented by the formula $ab = x = b' + \frac{1}{2}d'$, and for stone, $ab = x = b' + d'$. The subgrade is represented by *abf*. The pressure received by the subgrade from the tie is represented by the curves *agb* and *bhf*. The areas of the segments are small and the curves will approximate to parabolas and may be considered as such. The intensity of the pressure is proportional to the ordinates of the curve. Considering the curves as parabolas, the areas of the parabolic segments equal $\frac{2}{3}xy$; hence $\frac{2}{3}y$ is the mean ordinate and this is equal to the mean pressure. Therefore, the mean pressure is equal to $\frac{2}{3}$ the maximum pressure and the maximum pressure is equal to $\frac{3}{2}$ the mean pressure. The pressure at a and b on the subgrade is zero. If the tie-spacing S is such that the pressure curves *agb* and *bhf* intersect at b, the pressure is a maximum at y and is zero at b. In order to obtain an approximately uniform distribution of pressure over the subgrade the tie-spacing S must be such that the curves overlap, as *agb* and *eh'f'*, and have a common ordinate $y' = \frac{1}{2}y$. This will occur when $db = \frac{1}{4}cb$, or $eb = \frac{1}{4}ab$; or the tie-spacing $AC = \frac{3}{4}AB$. The pressure at d will then be $y' = \frac{1}{2}y$ from point A and also $y' = \frac{1}{2}y$ from point C, or the pressure

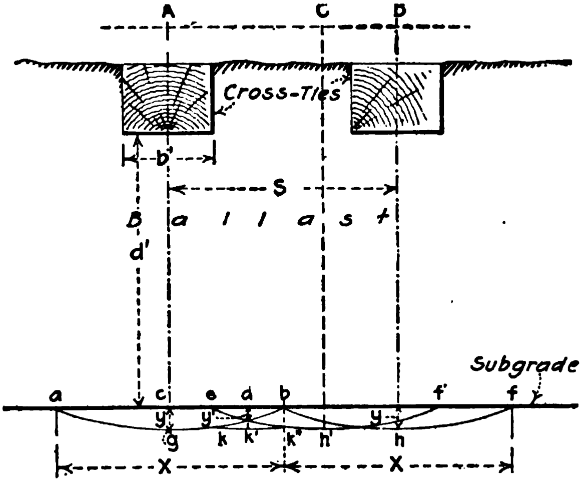

FIG. 109.—Distribution of the pressure over the subgrade.

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[1] Vol. 7, Proceedings, American Railway Engineering and Maintenance of Way Association.

at *d* will be $2y' = y$. Therefore, the actual pressure line will be $gkk'k''h'$, which approximates a straight line and a uniform pressure.

This solution is worked out for the pressure along a vertical plane parallel to the center line of the track. For a tie-spacing of 23 in. and width of 8 in. it gives a depth of 45 in. of gravel ballast for a uniform pressure on the subgrade, and a depth of 22 in. for stone ballast. Recent observations show that the pressure under the tie perpendicular to the center line of the track is not uniform. Fig. 110[1] represents the probable transverse pressure conditions. The diagrams show the deflections of the timbers of ballast-floor trestles caused by the passage of a train. Each type of floor-construction gives a different distribution of the pressure.

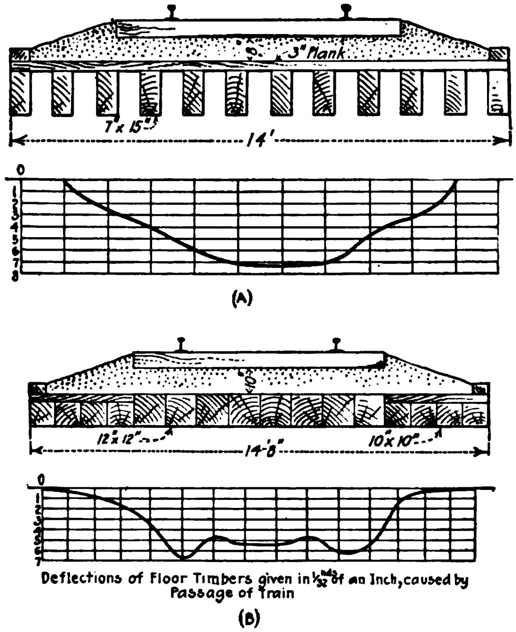
3" Plank
7 x 15"
14'
0
1
2
3
4
5
6
7
8
(A)
12 x 12"
14'-8"
10 x 10"
0
1
2
3
4
5
6
7
Deflections of Floor Timbers given in 1/32nds of an Inch, caused by Passage of Train
(B)

FIG. 110.—Pressure on the subgrade, transverse to the track.

These diagrams show that the pressure varies greatly in a line parallel to the tie. The tie-spacing and depth of ballast should be such that the maximum pressure at any point under the tie will not exceed the safe bearing power of the material composing the roadbed. It is of interest to observe that the two pressure curves in Fig. 110 correspond to the two forms in which water-pockets occur.

From the values given by the above formulas it will be seen that for the depth of ballast and tie-spacing ordinarily used by railways, an equal distribution of the pressure over the roadbed is not obtained.

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[1] Vol. 16, Proceedings, American Railway Engineering Association, pages 578 and 579.

However, if the maximum pressure at any point on the subgrade does not exceed the allowable bearing power no damage will result. As long as the roadbed can be kept dry and the depth of ballast and tie-spacing is that now used for Class A track, the loads it receives are within the safe bearing power of most materials. But when, because of improper drainage, water reaches the roadbed and softens it, the bearing power is greatly reduced and the roadbed is incapable of supporting the loads brought upon it by passing trains. Hence is seen the importance of keeping water from the roadbed. Table 15 gives the safe bearing power of soils under different conditions of loading and moisture.

TABLE 15.—SAFE BEARING POWER OF SOILS

	Material and conditions	Safe load in tons per square foot
1	Broken stone or gravel, unconfined, dynamic load (ballast).	2.0 to 3.0
2	Clay, made ground subject to frost, dynamic load (fills)...	1.0 to 1.5
3	Coarse cemented sand and gravel, static load, no frost.....	4.0 to 5.0
4	Wet sand in deep beds, static load, no frost..............	3.0 to 4.0
5	Wet sand in shallow beds over clay, static load, no frost..	0.5 to 1.0
6	Quicksand and saturated soils, static load...............	0.1 to 1.0
7	Dry earth according to depth below surface, static load.....	1.0 to 3.0
8	Moderately dry clay, confined, static load...............	2.0 to 4.0
9	Dry, stiff clay, static load............................	4.0 to 6.0
10	Dry sand, confined, static load.........................	2.0 to 6.0
11	Rock, depending on quality, static or dynamic load.......	25.0 to 200.0

CHAPTER XII

DESIGN OF RAILWAY-TRACK

169. General Design.—In designing any structure an attempt should be made to estimate a probable future increase in loading, and the design should discount the estimated increase for a reasonable period of time. The same method should be followed in designing railway-track, but usually such has not been the case. This results from two things, namely: (1) the belief of many engineers, almost since the introduction of the first locomotive, that the maximum limit of track loading had been reached, because to them it seemed impracticable to build engines and cars heavier than those in use, and (2) the construction of track without giving its design any scientific study. The layman's idea is that most, or all, railway-track is far too weak to carry safely the loads which actually it does carry with comparatively few accidents. In certain cases it is a fact that the traffic is too heavy for the track to carry with safety. But in practically all cases it can be said that new track is strong enough to carry safely its loads, and if an existing track is not strong enough to do this it is because of one of two things: either (1) maintenance has been neglected and the strength of the track has steadily decreased until it has become unsafe for its loads, or (2) the loads have increased so that the track, though well maintained and kept up to its original strength, is not strong enough to carry safely the heavier loads. Hence in designing track the two important considerations are: (*a*) to design each part of the track to withstand the stress in it from the loads on the track, which were discussed in the preceding chapter; and (*b*) what, if any, increase in total imposed loads, due to increased axle loads and increased speeds, can be expected.

170. Opinions of Engineers and Railway Officials.—The average age of 1000 locomotives in service on the Northern Pacific Ry. in 1908 was 10.4 years. If these 1000 locomotives are representative, the life of locomotives on that railway is 20.8 years. This means that about every 20 or 21 years there is a complete renewal of all locomotives. If the weight of locomotives is increasing, it might be expected that every 20 or 21 years it would be necessary to replace all bridges with stronger ones to carry the heavier loads. Table 16 gives the actual period of service of ten steel bridges before being replaced.

A steel bridge is considered to be a permanent structure, but Table 16 shows that this is not the case. The life of a structure is limited by increasing loads and not by the durability of the materials. The records of most railways which have existed over 20 years show that most track structures have been replaced from time to time by much stronger structures. It can readily be understood that this interval of premature renewal has differed considerably on different railways because the density of traffic and locomotive wheel loads, train loads, and speeds vary. Nevertheless, Table 16 shows that this interval varies less than might be supposed, as for seven of the structures the interval varies by but 2 years.

TABLE 16.—LIFE OF TEN STEEL BRIDGES

	Railway	Location of bridge	Year erected	Year replaced	Life in years
1	C. M. & St. P.	Rock River	1884	1903	19
2	Wabash	Sangamon River	1885	1906	21
3	C. B. & Q.	Big Rock Creek	1881	1903	22
4	Ill. Central	Big Muddy River	1889	1902	13
5	Ill. Central	Tennessee River	1888	1905	17
6	C. & N. W.	Kinnikinnic River	1880	1899	19
7	P. M.	St. Joseph River	1887	1904	17
8	Grand Trunk	Niagara River	1887	1906	19
9	C. M. & St. P.	Menominee River	1886	1903	17
10	C. R. R. of N. Y.	Newark Bay	1887	1904	17
			Average life		18.1

On page 726, 1912 edition, American Civil Engineers' Pocket Book, in discussing bridge specifications, it is said "The tendency is to use the heavier of the Cooper Classes, and as there are locomotives in service having loads slightly heavier than the E-50 it is only a question of a short time when greater loads will be commonly used for design of new bridges." In 1915 one important road in the United States was designing its structures by Cooper's E-65 specifications, seven by E-60, four by E-57 and at least five more planned to adopt a heavier loading in the near future. That all engineers do not agree that a future increase in loads is to be expected is shown by the fact that in 1913 Mr. J. E. Greiner[1] stated it as his belief that there was no necessity for designing a bridge for a loading heavier than Cooper's E-50, and that a structure designed for Cooper's E-60 loading would carry the heaviest load conceivable.

The above statements refer to bridges, but as track and bridge must carry the same load they apply equally to track.

During the past decade there has been a rapid increase in expenses over which railways have but a limited control, and the rising ratio of operating expenses to gross earnings has been a constant specter to the

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[1] A consulting bridge engineer of Baltimore, Md., and a 1914–15 Director, American Society of Civil Engineers.

American railway manager. To counteract this situation every means possible have been used to increase the freight train-load. Table 17 shows what ten individual railways have accomplished toward increasing their average train-load during the two 5-year periods ending with 1913. In 10 years the increase on the Kansas City Southern was over 100 per cent. These increased train-loads have been due in large measure to the use of more powerful and heavier locomotives, and the result has been an increase in both locomotive and car axle loads.

TABLE 17.—INCREASE IN TRAIN-LOADS ON TEN RAILWAYS
(Railway Age Gazette, April 10, 1914)

	Name of road	Average train-load in tons			Per cent. increase	
		1913	1908	1903	1913 over 1908	1908 over 1903
1	Canadian Pacific	381	291	252	31.0	15.6
2	Chesapeake & Ohio	843	621	473	31.8	26.1
3	Chicago, Burlington & Quincy	484	384	271	26.1	41.6
4	Delaware, Lackawanna & Western	660	484	443	32.5	9.25
5	Kansas City Southern	520	318	255	63.0	24.7
6	Norfolk & Western	764	571	486	33.9	17.5
7	Northern Pacific	542	431	326	25.9	32.2
8	Pennsylvania	719	602	527	19.5	14.2
9	Pittsburgh & Lake Erie	1241	1058	951	17.2	11.2
10	Wheeling & Lake Erie	789	612	400	28.9	53.0

There is no reason to believe that the cost of operation will not continue to increase. Recent grantings of freight rate increases by the Interstate Commerce Commission is a recognition of the fact. The question then arises: will the railways of the country be able in the next 10 years to overcome the increasing cost of operation by increasing the train-load as they have since 1903? An inquiry of this nature recently sent to the presidents and receivers of forty American railways brought some thirty-five answers.[1] All answers expressed the opinion that during the next 5 years the train-load would increase, but not to such an extent as since 1903. On some individual roads the maximum was thought to have been reached. Some officials were of the opinion that with the present form of motive power the heaviest locomotives now in service represented about the maximum economic tractive capacity, while about an equal number believed that the ability of mechanical engineers could indefinitely increase the tractive capacity of locomotives if money was available and traffic was of sufficient volume to demand the increase.

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[1] Railway Age Gazette, April 10, 1914.

All opinions agreed that in the future extensive grade reduction would be responsible to a considerable degree for increased train-loads.

There are but a very few roads having all locomotives of the heavier type. On all other roads the average weight of locomotives would continue to increase for some time, even though no heavier engines were built than those representing the present maximum.

171. Locomotive Axle Loads.—While the weight of locomotives is still on the increase, the weight did not increase as much between 1908 and 1915 as formerly. This is not due to the fact that there has been no development in the locomotive. The development in actual power of the locomotive has been, if anything, more pronounced recently than in earlier periods, but this additional power has been obtained by the invention and use of the superheater, the brick arch, the mechanical stoker, improved valve gear, etc., and not alone by additional weight. It cannot reasonably be expected that developments of this character will continue indefinitely, and if the operating department demands increased motive power it will soon be necessary to obtain most of this by increasing the weight on the drivers.

An important development in locomotive design during 1913 was the Atlantic type of passenger-engine produced by the Pennsylvania Railroad. For several years previous this road conducted elaborate experiments with this type of engine and the present result is an engine weighing 240,000 lb., with 138,000 lb. on the drivers, giving axle loads of 68,500 lb. The engine is so perfectly designed and balanced that the dynamic load is less than 30 per cent. in addition to the static load on the drivers, a dynamic load about the same as that of the ordinary engine having a static load of about 55,000 lb. per axle. During 1914 the same company produced a Mikado and a Pacific type of exceptionally high power and good design.

Of the locomotives built in 1914, the large locomotive was particularly in evidence, the record for weight and power being broken for the Pacific and Mikado types by two locomotives built for the Chesapeake and Ohio. A 2–10–2 type built for the Baltimore and Ohio had a total weight of 406,000 lb. and was the heaviest locomotive built up to that time on one set of drivers. Another development of much interest in locomotive design was the triplex compound articulated locomotive built early in 1914 by the Baldwin Locomotive Works for the Erie Railroad. This is the heaviest engine ever built, weighing 853,050 lb. complete and surpasses in size and power the Santa Fe and Virginian engines previously holding the record for size and power. Its distinctive feature is the placing of a third motive unit of 8 drive-wheels under the tender, so that the locomotive has 24 drivers, the wheel arrangement being 2–8–8–8–2. Its theoretical tractive effort is 160,000 lb. The axle loads of this engine are 61,900 lb. On the trial test this locomotive hauled a train of 250 loaded 100,000-lb. capacity cars and a caboose. Exclusive of engine, the train weighed 17,912 tons. The engine weighed 422 tons. The length of train was 8547 ft., the maximum speed was 14 miles per hour, and the maximum and minimum draw-bar pulls were 130,000 and 67,000 lb., respectively. A few years ago when the Mallet locomotive was first produced it was considered freakish, but today it is in general use on many roads. The average axle load of all recently built locomotives is between 50,000 and 60,000 lb., and while at present the above examples are extreme they indicate the tendency to increase the weight.

172. Car Axle Loads.—Writing in 1885, Mr. A. M. Wellington said:

> "The capacity of ordinary freight-cars has increased from 10 or 12 tons to 15 and 20 tons. In fact the 20-ton has already become the standard both for coal and all other traffic, and many 25-ton and not a few 30-ton cars have been built. It may confidently be expected that the average car-load will increase for many years. It has increased fully 50 per cent. in the past ten years (1875 to 1885)."

Mr. Wellington was correct in this as in most of his conclusions. The average car-load not only increased for many years but is still increasing. Today the 60,000-lb. capacity car is largely obsolete, having been superseded by the 80,000- and 100,000-lb. capacity cars. Many eastern coal-handling roads now use a standard 115,000-lb. capacity car. In 1914 the Chesapeake and Ohio ordered 1000 cars of 140,000-lb. capacity, and in 1913 the Norfolk and Western built 750 gondola cars of 180,000-lb. capacity. As the capacity of cars increases, the weight must also increase. The tendency is toward all-steel construction. The revenue load of many 40,000-lb. capacity cars is 56 per cent. of the total loaded weight. The revenue load of 60,000- and 80,000-lb. capacity cars seldom exceeds 68 per cent. The revenue load of the Norfolk and Western 180,000-lb. capacity cars is 75 per cent. of the total loaded weight. The weight of those cars is 65,600 lb. and when loaded, with the allowable 10 per cent. overload, their total weight is 263,600 lb. They are provided with six-wheel trucks, but even so, the axle load is 43,900 lb. The 140,000-lb. cars of the Chesapeake and Ohio weigh 56,500 lb. and when loaded, with overload, weigh 210,500 lb. These cars have four-wheel trucks, so that their axle load is 52,625 lb., which is more than that of many locomotives. These cars are designed for hauling coal and when it is considered that they will doubtless be run in solid trains pulled by a heavy locomotive the tremendous burden on the track can be realized.

Besides these heavy new cars there are a few special cars of still heavier build. In 1913 the three cars of largest capacity built up to that time were completed for the Lehigh Valley. Their capacity is 220,000 lb. each and, when overloaded, give axle loads of 55,600 lb. on six axles. However, in spite of their excessive weight their effect on the track will be much less than the heavy cars of the Norfolk and Western and the Chesapeake and Ohio, because the special cars will not be run in solid trains. The same tendency to increase the weight is seen in the construction of passenger-cars, where steel is rapidly taking the place of wood. Although the first steel passenger-car was built about 1907, practically no wooden cars are now being built. On January 1, 1915, 284 railway companies operating 245,721 miles of road in the United States reported 62,112 cars in passenger service, 20.8 per cent. of which were all-steel. The percentage of all-steel to the total number of passenger-cars acquired each year by these railways increased from 26 per cent. in 1909 to 74.6 per cent. in 1914. Many Pullman cars have recently been built which weigh upward of 170,000 lb.

Steel passenger-cars weigh from 10 to 25 per cent. more than those of wood. The result is an increase in dead weight; besides, these cars are operated in solid trains. Another result of the use of steel passenger-cars is that the additional weight has required the use of heavier locomotives in order to maintain existing schedules. Experiments recently made on the Canadian Pacific and the Pennsylvania show that the steel passenger-equipment may create as high stresses in the track as many locomotives.

It is thus seen that the weight of every class of rolling-stock is increasing, yet the statement is now being made by some engineers that the limit has been reached on account of clearance conditions. In some cases the present limits have been reached. It seems probable, however, that in the near future radical changes will be made in clearance legislation. Also in the large uncrowded districts of the West there should be but little trouble in increasing the clearance limits if weights cannot otherwise be increased. The clearance limitations of the two-cylinder locomotive might be overcome by the adoption of a three-cylinder arrangement.

173. Speed of Trains.—Next in importance to the actual wheel loads carried by the track is the effect of high speed. Yet the present tendency is not to increase speeds but if anything to reduce them. This is especially true with heavy freight-trains. Also the increase in weight of the passenger-engines has counterbalanced the increased power so that the heavier but more powerful engines have not been able to show any increase in speed over the older engines. In order to handle heavier passenger-trains many roads have recently adopted the Pacific type in place of the Atlantic type of locomotive, because of the greater tractive power of the former. Greater power is thus obtained but the internal friction is much greater in the Pacific type than in the Atlantic type so that nothing is gained in speed.

A study of the schedules of fast trains shows that since 1895 there has been little change in speed. But, though the speed has not increased, heavier trains are being hauled at about the same speed.

The average speed of British express-trains is slightly above that of American trains but their runs are shorter. However, the fastest run is scheduled in America. The Pennsylvania from Atlantic City to Camden, N. J., a distance of 59 miles, makes the run in 52 min., or at an average speed of 68.1 miles per hour. The record schedule in England is from London to Bristol over the Great Western, a distance of 118 miles, at an average speed of 59.2 miles per hour. The longest fast run is from London to Plymouth, also over the Great Western, 246 miles at an average speed of 55.7 miles per hour.

The best performance of American roads is the train over the New York Central and Lake Shore between New York and Chicago, a distance of 964 miles. The average speed is 53.5 miles per hour and the train often carries seven cars for part of the distance. The next best time is over the Pennsylvania between Jersey City and Chicago, the distance being 905 miles, and the average speed 50.9 miles per hour. Some of the records for steam-locomotives are as follows:[1]

1. In 1880 a 4–4–2 engine with train made a record on the Great Northern Railway, England, of 66.5 miles per hour for 105.5 miles.
2. On May 9, 1893, a 4–4–0 engine with four cars maintained a speed of 102 miles per hour for 1 mile on the New York Central.
3. On May 19, 1893, a 4–4–0 engine with cars averaged 100 miles per hour for 5 miles on the New York Central.
4. On July 14, 1897, a 4–4–0 engine and four cars averaged 80 miles per hour for 44 miles on the Lehigh Valley.
5. On January 1, 1901, a 4–6–0 engine and three cars averaged 107.9 miles per hour for 5.8 miles on the Sav., F. & W.
6. On March 24, 1902, a 4–6–0 engine and nine cars averaged 98.66 miles per hour for 14.8 miles on the Burlington.
7. On December 15, 1905, a competition for the contract to carry the transcontinental mails was completed and an average speed of 50 miles per hour was made from Los Angeles to Chicago over the Atchinson, Topeka and Santa Fe, a distance of 2246 miles. At the same time an average speed of 44.3 miles per hour was made from Oakland, Cal., to Jersey City, N. J., over the Southern Pacific, Union Pacific, Chicago and Northwestern, Lake Shore and Michigan Southern, and Erie, a distance of 3239 miles.

For distances under 15 miles the speed record is held by the electric locomotive tested on the Berlin-Zossen line in Germany in 1903 when a speed of 130 miles per hour was attained.

The opinions expressed by Mr. Jacomb-Hood, of the London and South Western Railway, Mr. Herman Rosche, of the Sussig-Teplitz Railway, Austria, and Mr. Blumm, of the Prussian Board of Public Works, in papers presented in 1910 before the International Railway

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[1] 1909 Locomotive Dictionary.

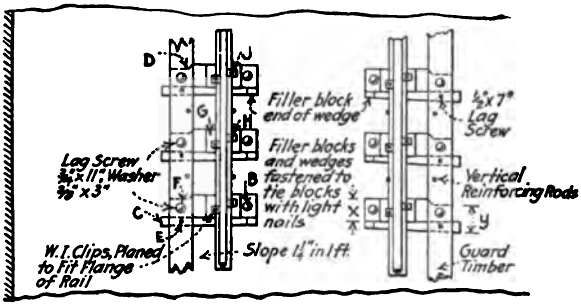
Congress, were that train speeds would increase in the future but that the strength of track was sufficient to carry much higher speed than any then in use. Mr. Jacomb-Hood thought that in England in the future an average speed of 70 miles per hour, necessitating a running speed of about 100 miles per hour, could be expected for long, fast passenger-runs. He considered existing track sufficiently strong to carry safely such speeds. Though the opinions of these men were that speeds would increase, it should be observed that none of the records given before have been made recently and the fact remains that the tendency at present, at least in America, is not to increase speeds. The principal objections to speed are the exaggerated effects of small irregularities of track and the shocks from unbalanced wheels.

174. Special Types of Track.—The tamping of the ballast under the ties in such a way as to give a firm and even bearing for each tie is one of the most important features in the work of track maintenance. But with from 2560 to 3360 ties per mile of track the conditions of labor—even experienced—and material make it impossible to attain anything closely approaching ideal conditions in this respect. The result is that the rail rests on intermittent supports of varying stability, yielding unequally under traffic. While the individual parts of the track have been considerably studied and developed, the track as a whole has received but little attention, and we find, in general, that the track structure today is much the same as it was some 70 years ago. A few engineers, realizing the defect of the cross-tie as a rail support, have experimented on a small scale with radical innovations or special types of track, but it can be said with reasonable certainty that for many years to come no new form of track will be universally adopted. From time to time the idea of supporting the rail on continuous longitudinals is revived. Many of the special types of track make use of the longitudinal. In general, the longitudinal on open track has not been a success. As a rule the special types are constructed to meet unusual conditions such as exist in tunnels, subways, and terminals.

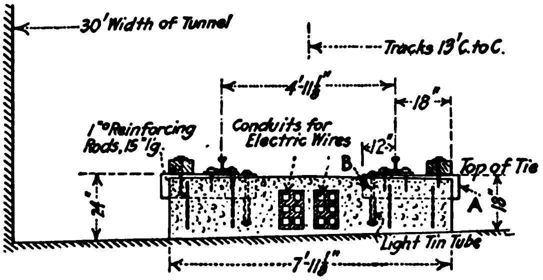
A system of track-construction invented by Mr. W. H. Coffman has as its special features the elimination of cross-ties and the reliance upon a thoroughly compacted and deep bed of stone ballast to carry the load. In this system the rails are supported at the joints by short pieces of steel channels. Between the joints the rail rests directly on the ballast which is expected to be so solidly rolled by a steam-roller that it will carry the load from the rail without settlement. The gage is maintained by steel tie-bars which grip the base of each rail. Each of these bars is anchored in the ballast by a vertical rod attached at the middle of the bar and anchored in a concrete block which is embedded in the ballast. For heavy traffic the ballast should be from 18 to 24 in. deep and several intermediate channel-bar supports are introduced.

A concrete roadbed can be used in one of two ways: (1) placing a separate line of continuous concrete beams or stringers under each rail; or (2) placing the track on a concrete floor. Steel or concrete continuous longitudinals can be used in two ways: (1) laying the longitudinals in a deep gravel or stone ballast and allowing the ordinary cross-ties to rest on the longitudinals; or (2) placing the rail directly on the longitudinal, to which it is fastened.

175. Special Track in Tunnels.—Railway tunnels and subways offer special opportunities for a more permanent system of track-construction, because the tunnel, with its rock floor or masonry invert, offers a solid foundation for the track, making it unnecessary to provide a bed of ballast to take up any settlement of the roadbed. The rails in the Philadelphia subway are fastened with clips to short wooden blocks 6 in. thick. The blocks rest on two longitudinal channels embedded in concrete. A track in which the ties are embedded in concrete at the center and have the ends embedded in stone ballast has been used in some of the London tubes. This has proved satisfactory even though it produces a center-bound track, violating the generally accepted principles of track-construction.


D
J
G
H
B
F
C
E
Filler block end of wedge
Filler blocks and wedges fastened to tie blocks with light nails
Lag Screw $\frac{3}{4}$"x11", Washer $\frac{3}{16}$"x3"
W. I. Clips, Planed to Fit Flange of Rail
Slope $1\frac{1}{4}$" in 1 ft.
$\frac{1}{2}$"x7" Lag Screw
Vertical Reinforcing Rods
x
y
Guard Timber

Part Plan



Part Section

FIG. 111.—Special track-construction, Bergen Hill tunnel, D. L. & W. R. R.

The special track-construction, known as the Bush system, used in the Bergen Hill tunnel (Jersey City, N. J.) of the Delaware, Lackawanna and Western is shown in Fig. 111. The tunnel is 4280 ft. long, is double track, and is driven through solid rock. Upon the rock floor are two continuous beds of concrete about 8 ft. wide and 20 in. thick, spaced 13 ft. center to center. Each of these beds carries one of the tracks. Recesses are cast about 29 in. apart center to center along each side of the bed into which are set wooden blocks (*A*), Fig. 111. The blocks are 30 in. long and are held in place by anchor-bolts (*B*), wooden wedges (*C*), and a shoulder (*D*) in the recess engaging a similar shoulder on the block. A 6- by 8-in. guard-timber is fastened to each block by lag-screws (*F*). The blocks and wedges are creosoted pine. Each block carries a flat wrought-iron tie-plate (*G*). The rail is held by screw-spikes (*J*) which bear against square rail-clips (*H*). The mouth (*y*) of the recess is wider than the width (*x*) of the block. When a block is to be removed all screws holding the block and wedge are withdrawn, the wedge is removed and the block is moved sidewise until it can be pulled out. It was estimated that ordinary ballasted track of the best character would cost $10.15 per foot of double track, while the actual cost of the special track was $13.18 per foot of double track, exclusive of conduits in each case. With conduits the actual cost was $14.26 and the estimated cost for ordinary track was $14.62. The greater cost of the latter was due to the fact that with ballasted track it would have been necessary to cut channels in the walls of the tunnel for the conduits, or else place them in special construction along the side walls, below base of rail. The advantages of the construction used, over ordinary track, are: (1) A permanent surface and line. (2) The cost of maintenance is reduced to but little more than inspection. (3) The renewal of the blocks is much simpler than the renewal of the ties would be under conditions existing in the tunnel.

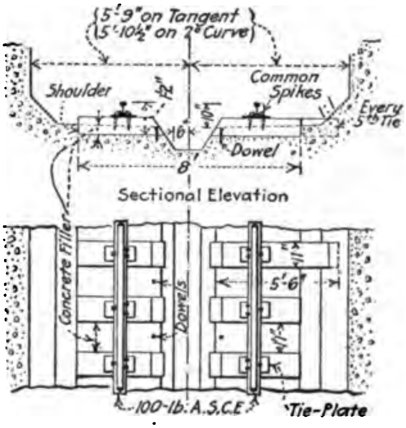


Fig. 112.—Track-construction in the Detroit River tunnels, New York Central Lines.

The type of track-construction used in the Detroit River tunnels of the New York Central Lines is shown in Fig. 112. The tunnel is 8360 ft. in length and consists of twin tubes each carrying one track. The invert of each tube was built to the full outer lines shown in the sectional view. The rails rest on short wooden blocks. The outer end of each block abuts against a shoulder cast in the concrete and effectually prevents any spreading of the rails. A gutter is provided on the center line of the invert and the inner end of each block is cut to the side slope of the gutter. The concrete filler between ties was placed after the invert was cast and is keyed to it by 1-in. round dowel pins 7 in. long, which were embedded in the invert while the concrete was fresh. The wooden blocks are untreated pine. No direct provision is made to prevent an inward movement of the blocks.

While most of the track of the New York tunnels of the Pennsylvania Railroad is of the standard ballasted type, a short section of track having a concrete base was put in the land section of two of the tubes and 14,600 ft. of similar track was built adjacent to passenger-platforms in the Pennsylvania Station. At the station, where oil and water drips from standing cars and rubbish is thrown on the track by passengers, it was desired to provide a form of construction which would present a smooth surface and could be cleaned readily. The rails were laid on short wooden blocks and the concrete poured flush with the top of the blocks to the inner ends. A gutter was formed along the center of the track by keeping the top of the concrete between the blocks level with the bottom of the blocks. The track cost $8.94 per linear foot.

176. English Track on the Pennsylvania Railroad.[1]—In the middle eighties, Mr. F. Thompson, then second vice-president of the Pennsylvania Railroad, while abroad became interested in the question of comparative merits between English and American track. Accordingly he authorized the purchase of sufficient materials to construct 2 miles of track duplicating the standard track of the London and North Western Railway. His idea was to compare this English track with American track under American conditions.

In order to give the track a fair trial it was distributed among the four main-line divisions of the Pennsylvania Railroad, ½ mile being built on each division, so that it would have different roadbed, different climatic conditions and different sets of men to care for it, watch and record its performance, and make the final comparison between it and the standard American track. The track was laid in 1887 and 1888. The trial was made on first-class roadbed with the result that the English track had an average life of about 5 years as against about 10 years for the Pennsylvania's standard track. Both the first cost and the cost of maintenance were about twice as much for the English as for the American track. The English track was very unsatisfactory. It was difficult to keep the track to true line and surface, creeping was excessive, and the wooden wedges worked loose.

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[1] Vol. 14, Proceedings, American Railway Engineering Association.

CHAPTER XIII

SIGNS, FENCES, AND HIGHWAY CROSSINGS

177. Roadway Signs.—Roadway signs are used for three general purposes: (1) To mark special points of boundaries, distance, and track alignment for reference purposes and particularly for the information of the maintenance forces. (2) As fixed signals or signs to convey certain information to the trainmen. (3) To convey certain information and warnings to patrons of the railway and to other persons.

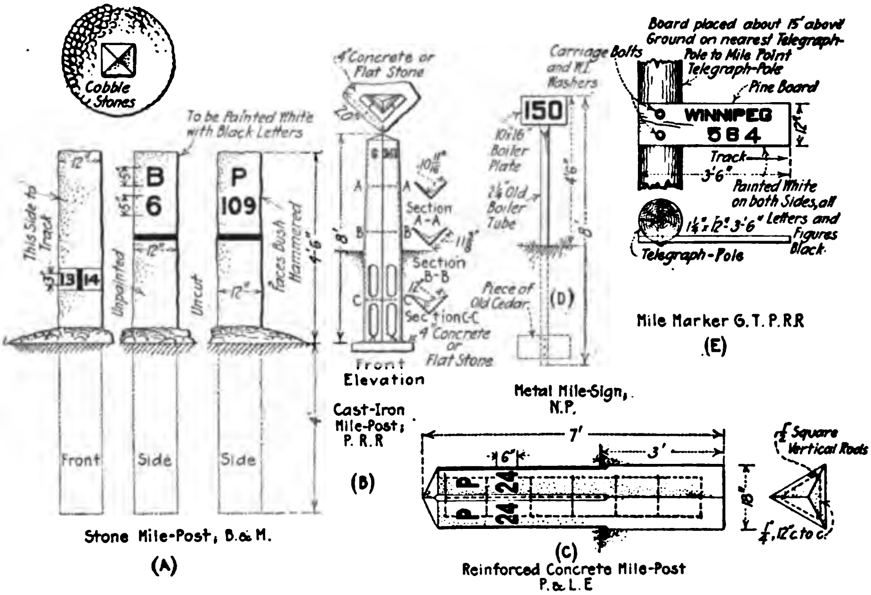
Signs should be placed in a conspicuous place, and once established must not be moved without permission from the division superintendent or other proper authority. The exact location, position, distance from the track, wording and side of track depend on the purpose for which the sign is used. In some States one or more of these is fixed by law. All signs governing the movements of trains must be placed on the engineman's side of the track. The signs must be painted often enough to keep them perfectly legible. One painting each 3 years will usually be sufficient. Plain black letters on a white background are used for most signs, though black letters on a red or yellow background, and white letters on a black or blue background are occasionally used.

178. Design, Material, Life, and Cost of Signs.—Signs are of three general forms: a simple post; a plate or board fastened to a special post; a plate or board fastened to an object primarily used for other purposes, as to a bridge, building, telegraph-pole, etc. Decorative signs of floral designs or of whitewashed hand-placed stones are often used in station-grounds.

The materials used are wood, metal, and concrete. Stone mile-posts are used by a few railways. Wood was first used, is still mostly used and is the most satisfactory and economical material for large signs. Metal is used considerably for signs of medium size and complicated form, and is satisfactory. Concrete is the least used of all, but its use, particularly for posts and small signs of simple form, is practical and is increasing.

The ends of the posts carrying large signs should be set in concrete. Wood and metal are subject to deterioration from the action of the elements, while concrete is affected to a much less extent. Metal and concrete signs and posts have not been used long enough to determine their life. The quality of the concrete has an important bearing on the life of all concrete structures. Concrete signs must be designed along mathematical lines in order to keep the cost within reasonable bounds. In general, this means first-class material and workmanship throughout, and a light structure. Metal signs are made of cast iron, wrought iron, wrought steel, a combination of the three, old rails, and old boiler flues. A combination of a wrought post and cast plate is a common practice.

The life of metal signs depends on the condition of the tubes, plates or other metal when first installed and the means used to protect them. Old boiler flues and other hollow posts should be filled with concrete. If the ends of tubular posts of small diameter are not set in concrete a piece of 1-in. gas pipe about 18 in. long should be run through a hole at a right angle to and near the bottom of the post, to prevent turning of the post. The life of all metal and wood posts will be increased if they are set in a block of concrete extending several inches above the ground. All exposed surfaces should be protected by paint. The life of metal signs protected in this manner is probably from 30 to 40 years. The life of well-designed concrete signs is about the same, while the life of wood signs is from 10 to 20 years, depending on the protection employed and whether the posts are treated or untreated.



Stone Mile-Post, B.& M.
(A)

Cast-Iron Mile-Post; P. R.R
(B)

Reinforced Concrete Mile-Post P.& L.E
(C)

Metal Mile-Sign, N.P.

Mile Marker G.T.P.RR
(E)

FIG. 113.—Mile-posts and -signs.

Concrete posts and signs should be allowed to season from 30 to 60 days before being installed. They must be handled very carefully to avoid damaging them. Their cost is from $1.00 to $3.00 each, the cost of shipping and distributing is from 50 to 75 cts. each, and the cost of installation is from 25 cts. to $2.00, averaging close to a dollar. The cost of 12-in. by 12-in. by 7-ft. mile-posts on the Florida East Coast was $2.00 each, while 12-in. by 12-in. by 7-ft. 6-in. triangular mile-posts have cost $2.50 on the Pennsylvania Lines West. The Queen and Crescent, and New York, Chicago and St. Louis have used a mixture of 1 part cement, 2 parts sand, and 4 parts stone. The Lake Erie and Western has used 1 part cement and 4 parts gravel not over ¾ in., while the Central of Georgia uses a wet mixture consisting of 1 part cement and 2 parts sharp river gravel.

The cost of metal signs varies considerably on different roads. The mile-post used on the Northern Pacific, shown at (*D*), Fig. 113, is made of an old boiler flue, a piece of boiler plate, and a piece of old tie, and costs 50 cts., while the trespass-sign of the Pennsylvania Lines West (*D*), Fig. 121, costs from $4.50 to $4.75. The speed-limit sign shown at (*A*), Fig. 119, costs $7.00 and the yard-limit sign shown at (*C*) costs $6.50. The cost of installing metal signs averages about $1.00 each, while distribution averages about 50 cts. each.

Wooden signs cost less than those of concrete or metal but their life is also less. The highway-crossing sign of the Grand Trunk Pacific (*A*), Fig. 120, costs $3.55, while that of the St. Louis Southwestern, shown at (*D*), costs $6.75.

179. Signs Used to Mark Special Points.—Mile-signs are of three forms: (1) Round, triangular, or square posts containing either one or two sets of numbers. If there is one set of numbers these should face the track. If there are two sets, the sets may be placed on adjacent faces and the post set so that the numbers face the track at an angle of 45°, or the numbers may be on opposite faces and the post set so that the numbers face in each direction along the track. (2) A post with one or two number-boards placed so that the numbers face the track directly, or at an angle of 45° in each direction, or parallel to the track in each direction. (3) One or two number-boards fastened to a telegraph-pole and facing as above with respect to the track.

Mile-posts are constructed of wood, metal, concrete and occasionally stone. They are usually placed so that the set of numbers refers to the distance from the end of the division or terminal which the number faces. However, the Pennsylvania and several other roads place the numbers so that on approach, the distance to the terminal beyond is indicated. The Boston and Maine sets the posts as near to 15 ft. from the outer rail as practicable. Mile- and division-posts on the Pennsylvania are set not less than 8 ft. from gage of rail on fills, and 11 ft. elsewhere. This allows the posts to be placed at the shoulder of the roadbed on fills and at the foot of the slope in cuts. Mile-posts are set 8 ft. 3 in., in the clear from gage of rail on the Erie, and 8 ft. 6 in. on the Delaware, Lackawanna and Western. Posts should not be set in the face of the slope of either cuts or fills. On the Northern Pacific mile-signs are located 6 ft. 9 in.

from the rail to center of post on right-hand side of track going west. Mile-posts should be on the engineman's side, but this would mean placing posts on each side of the track. Since only one set of mile-posts is used, it makes no difference on which side they are placed, as long as they are all on the same side. Different types of mile-posts and mile-signs are shown in Fig. 113.

At divisional points and at the ends of sections posts or signs are placed which bear the number or name of the section or division. Section-signs are necessary to mark the boundaries of each section-foreman's territory. These often consist of a board attached to a telegraph-pole in a manner similar to that shown at (*E*), Fig. 113. Two other forms of section-signs are shown at (*A*) and (*B*), Fig. 114. The numbers should face the section to which they refer. If the sections divide at a mile-post the numbers may be placed on the mile-post, as at (*A*), Fig. 113.

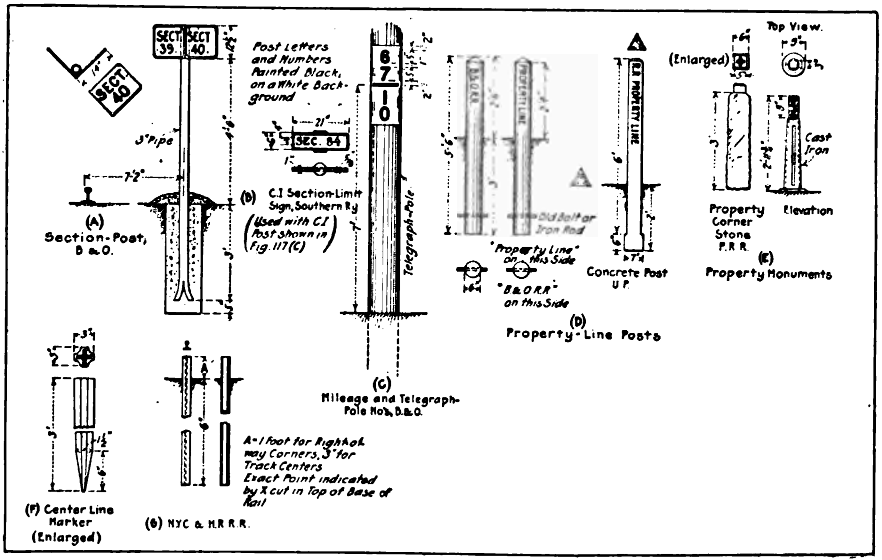

SECT 39
SECT 40
SECT 40
14"
3" Pipe
7'-2"
4'-6"
3'
(A) Section-Post, B & O.
Post Letters and Numbers Painted Black, on a White Background
21"
SEC. 84
(B) C.I Section-Limit Sign, Southern Ry (Used with C.I Post shown in Fig. 117 (C))
6
7
1
0
Telegraph-Pole
7'
(C) Mileage and Telegraph-Pole No's, B & O.
B & O R.R.
PROPERTY LINE
5'-6"
Old Bolt or Iron Rod
"Property Line" on this Side
"B & O R.R." on this Side
(D) Property-Line Posts
U.P. PROPERTY LINE
6'
Concrete Post U.P.
7"
Top View.
(Enlarged)
Property Corner Stone P.R.R.
Elevation
Cast Iron
3'
(E) Property Monuments
3¾
5'
1½"
(F) Center Line Marker (Enlarged)
A
(G) NYC & H.R R.R.
A = 1 foot for Right of way Corners, 3" for Track Centers
Exact Point indicated by X cut in Top of Base of Rail

FIG. 114.—Section, telegraph-pole, and property signs.

It is customary for trackmen to designate a certain point along the track by giving the number of the nearest telegraph-pole or the number of telegraph-poles beyond a certain mile-post. Hence it is desirable to have the telegraph-poles numbered. The method used on the Baltimore and Ohio, illustrated in Fig. 114 (*C*), is to number every fifth pole. Black figures on a white background are used and the numbers are duplicated on opposite sides of the pole. The number of the first mile-post east of the pole is placed above a horizontal line, and the number of poles west of the mile-post is placed below the line. The number in the figure is for the tenth pole west of mile-post 67.

It is sometimes desirable to indicate the boundary of unfenced land by property-line posts (Fig. 114, *D*). These should be set entirely on the railway property with one face on the property-line. Only enough of these posts are required to definitely mark the lines between corners. At all property-corners permanent monuments should be set. Two kinds of property-monuments are shown at (*E*) and another at (*G*), Fig. 114. On single track the center line of the track should be definitely marked by setting permanent monuments at the beginning and end of spiral, beginning and end of curve, compound curve points, etc., and at sufficient intervals around the curve to make it possible to see one monument from the next. On double track, if the curves are concentric, the center between tracks should be thus marked, but if the curves are not concentric the center line of each track must be marked. A wrought-iron pin about 1½ in. in diameter and about 42 in. long makes a good track-center monument. The length will depend on the character of the

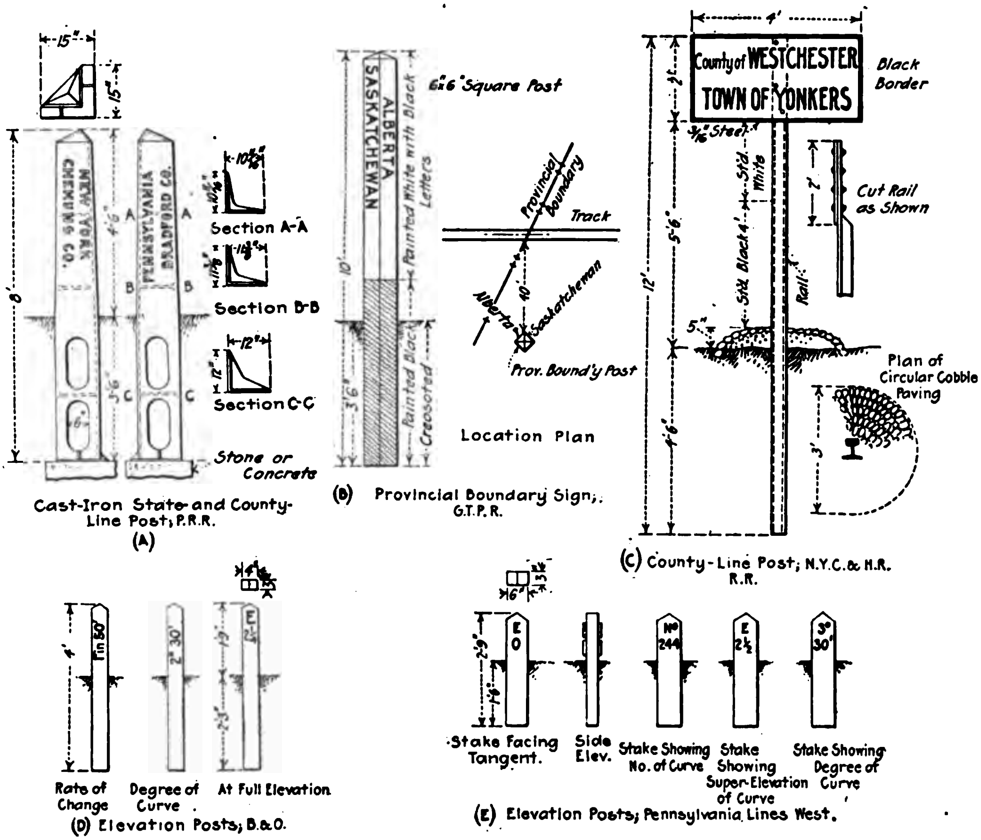


FIG. 115.—State-line and elevation posts.

roadbed. The cast-iron post used by the Pennsylvania is shown at (*F*) and the marker used by the New York Central is shown at (*G*), Fig. 114.

State, Provincial, and County line posts are shown at (*A*), (*B*) and *C*), Fig. 115. One method of locating these is shown at (*B*).

At points of change from tangent to curve and at points of change in curvature, elevation posts should be set. These should give the amount of superelevation, the degree of curve, the designation of the point, as T-S (tangent-spiral), etc., and the number of the curve. For one track, or for more than one track if the elevation is the same, the posts should be set from 7 to 8 ft. from rail on outside of curve. If there are two or more tracks and the elevation is different, one set of posts referring to the outer track should be set outside the curve and another set, referring to the inner track, should be set inside the curve. If the curve is spiraled a stake should be set at the B. S. and marked "E. 0" (elevation zero) facing the tangent. At the end of spiral another post should be set, which has the full elevation marked on it facing the curve to which the elevation applies. The same rule holds for compound curves with or without spirals. If the curve has no spiral half the elevation is given on the tangent and half on the curve, an elevation post being set at the beginning and end of the elevation and a track-center monument set at the true B. C. Elevation posts are usually made of oak, yellow pine, cedar, or chestnut, and the portion set in the ground should be dipped in or painted with creosote, coal-tar, or some other preservative. Some

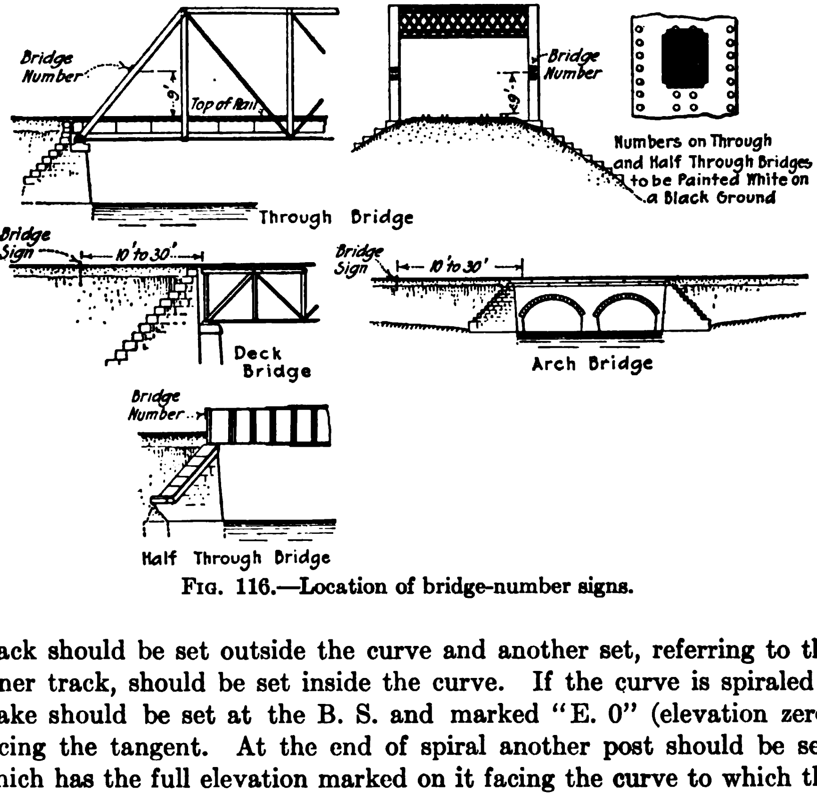
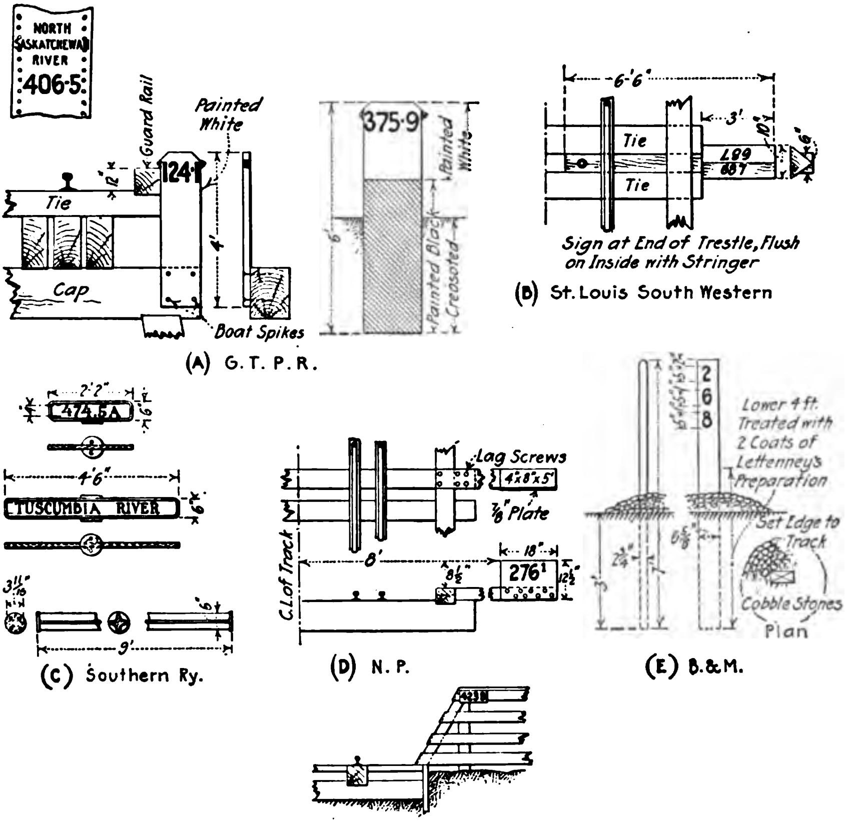


FIG. 116.—Location of bridge-number signs.

railways use white letters on a dark background while others use the reverse. Elevation posts are shown at (*D*) and (*E*), Fig. 115.

The number-plates of through and half-through bridges are placed on the end posts of the trusses, or on the ends of the girders. The number of a deck-bridge, trestle or culvert is placed either on a plate or board fastened to the structure, or on a post placed from 10 to 30 ft. from each end of the structure. The location of the number-plate for through,



(A) G.T.P.R.

(B) St. Louis South Western

(C) Southern Ry.

(D) N.P.

(E) B.&M.

(F) Cattle-Guards; U.P.&S.P.

FIG. 117.—Bridge-number signs.

half-through, and deck-bridges and for culverts is shown in Fig. 116. The numbers should be placed on both sides at both ends of all double-track through and half-through bridges and all other bridge structures over 100 ft. in length. In addition to the number, bridges over important streams have a name-plate. Some railways number all openings as bridges while others have a separate set of numbers for bridges and culverts, all openings less than 6 ft. in diameter or 10 ft. in span being classed as culverts. The numbers either refer to the consecutive number of the bridge from the terminus or junction from which the mileage starts, or correspond to the distance of the center of the bridge from the reference point. In the latter system, which is the preferable one, each number usually is in two parts, the first part representing the miles and the second part the hundredths of a mile. Several forms of bridge-signs are shown in Fig. 117.

180. Fixed Signals.—Fixed signals include all signs which directly affect train movements or the conduct of trainmen. Stop-signs are placed from 200 to 400 ft. on each side of uninterlocked drawbridges and railway crossings. Other warning-signs may be placed in advance of these. The Northern Pacific Railway places three signs at the approach to all such bridges and crossings. A sign bearing the words "R. R. Crossing 1 Mile" is placed 1 mile from the crossing. Eight hundred feet from the crossing a second sign is placed bearing the words "R. R. Crossing 800 Ft.," and a stop-sign is placed 200 ft. from the crossing.

Whistle-signs are placed 1320 ft. on each side of highway crossings and about 2000 ft. from the outlying main-line switch to the yard at stations. Ring-signs are placed where curvature, cuts, or other obstacles obstruct a view of the track. These require the engineman to continuously ring the bell until the obstruction is passed. This is done to warn persons crossing the track or working on the track of the approach of the train and in a measure to protect the train itself. There are often speed restrictions within city or yard limits and these points should be marked with proper signs. Reduce-speed signs, or slow-signs may also be required at these points and are also placed at the approach to sharp curves, old bridges, long bridges and tunnels, etc., where safety demands that the speed be restricted. Resume-speed signs are placed at the point where speed may be resumed, though the use of these is not as common as that of slow-signs. Slow-signs are used temporarily by the trackmen when doing any work which seriously disturbs the surface or stability of the track. The Boston and Albany Railroad places a reduce-speed sign 3000 ft. from each slow-sign so that the train can be brought to the reduced speed before reaching the slow-sign; if there are more than two tracks the number of the track to which the sign refers is also added and a resume-speed sign is placed at the other end of the restricted territory. The reduce-speed signs have black letters on a yellow field, and the resume-speed signs have black letters on a green field.

Clearance-posts are placed at the turnout-ends of all side-tracks as a warning to trainmen against leaving cars on one track which will foul the other track. A clearance-post is set at the point where the distance between track centers is 12 ft. It usually consists of a low post marked with the letter "C," but in yards a rail-brace is often placed on the tie at the clearance point and is painted vermilion.

A warning-sign reading "Station 1 Mile," or "Water 1 Mile," etc., should be placed 1 mile on each side of all such points. A flanger-sign must be placed from 50 to 150 ft. in advance of all turnouts, railroad

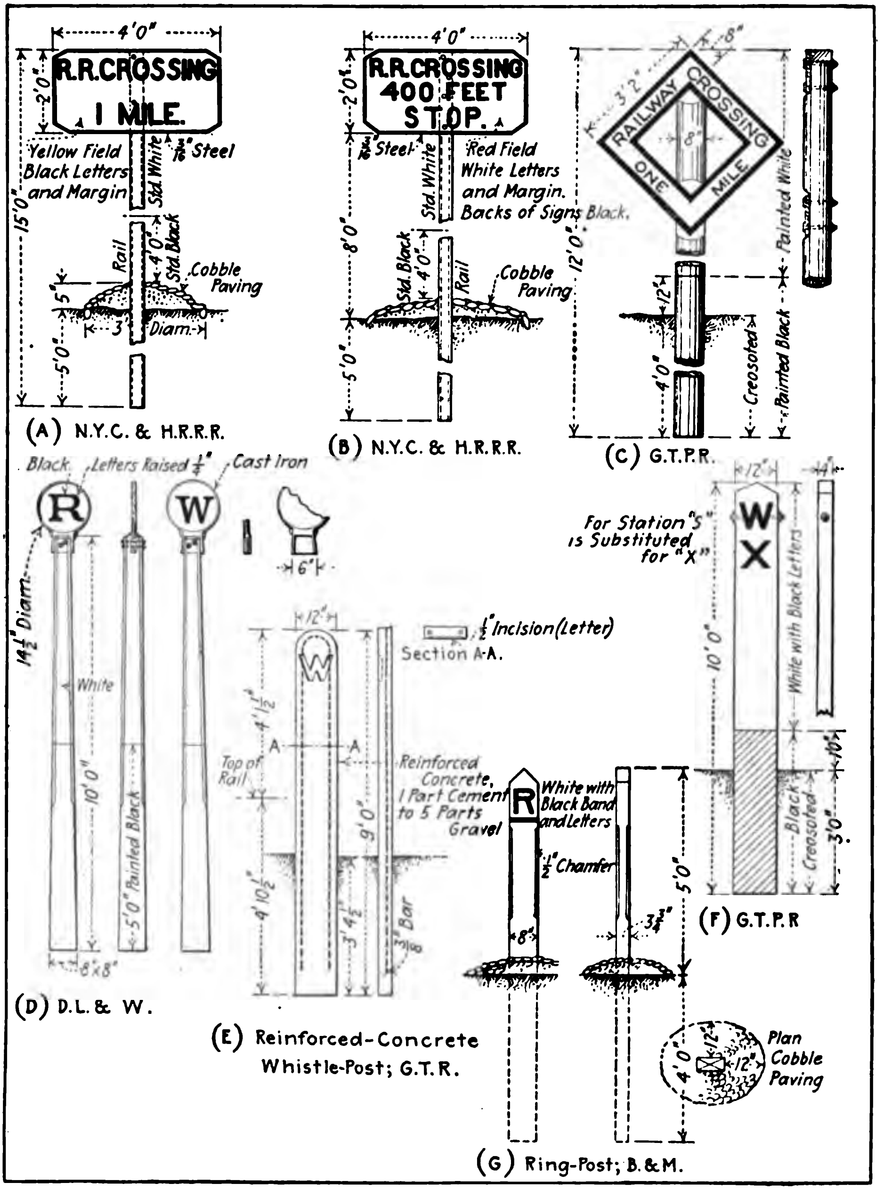


FIG. 118.—Fixed-signal signs.

crossings, stock-guards, and road crossings as a warning to the operators of flanger-cars. A derail-sign should be placed opposite each uninterlocked

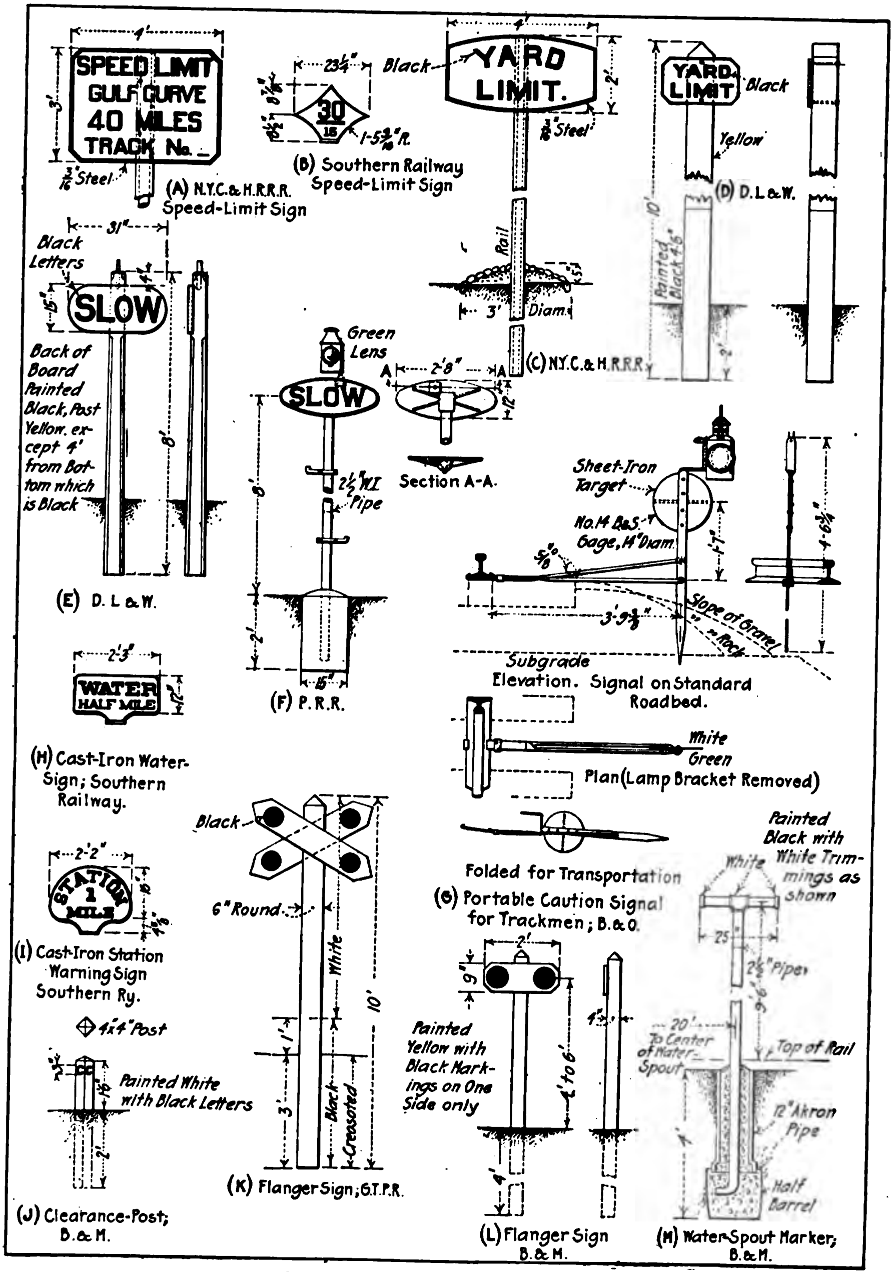

4'
3'
SPEED LIMIT
GULF CURVE
40 MILES
TRACK No.
3/16" Steel
(A) N.Y.C.& H.R.R.R. Speed-Limit Sign
23¼"
Black
30
15
1-5¾" R.
(B) Southern Railway Speed-Limit Sign
4'
YARD LIMIT.
2'
3/16" Steel
Rail
3'
5"
Diam.
(C) N.Y.C.& H.R.R.R.
YARD LIMIT
Black
Yellow
(D) D.L.& W.
10'
Painted Black 4'6"
4'
31"
Black Letters
SLOW
15"
Back of Board Painted Black, Post Yellow, except 4' from Bottom which is Black
8'
(E) D. L. & W.
Green Lens
SLOW
A
2'8"
12"
2½" W.I. Pipe
Section A-A.
8'
2'
15"
(F) P.R.R.
Sheet-Iron Target
No.14 B.&S. Gage, 14" Diam.
5/8"
1'-7"
3'-9½"
Slope of Gravel
Rock
Subgrade
Elevation. Signal on Standard Roadbed.
4'-6¾"
White
Green
Plan (Lamp Bracket Removed)
Folded for Transportation
(G) Portable Caution Signal for Trackmen; B.& O.
2'-3"
WATER HALF MILE
12"
(H) Cast-Iron Water-Sign; Southern Railway.
2'-2"
STATION 1 MILE
18"
(I) Cast-Iron Station Warning Sign Southern Ry.
4x4" Post
18"
Painted White with Black Letters
2'
(J) Clearance-Post; B.& M.
Black
6" Round
White
10'
1'
3'
Black
Creosoted
(K) Flanger Sign; G.T.R.R.
2'
9"
Painted Yellow with Black Markings on One Side only
4' to 6'
4'
(L) Flanger Sign B.& M.
Painted Black with White Trimmings as shown
White
25"
2½" Pipe
20" To Center of Water Spout
Top of Rail
12" Akron Pipe
Half Barrel
4'
(M) Water-Spout Marker; B.& M.

FIG. 119.—Fixed-signal signs.

derail or derailing switch as a warning to switchmen and to persons on hand- and motor-cars. The sign bears only the word "Derail," which is painted on both sides. At points where it is permissible to dump the ash-pans of the locomotive, a sign bearing the word "Cinders" or "Dump Cinders" is placed on the fireman's side of the track. With the exception of clearance-, cinders- and derail-signs all other signs described in this article are placed on the engineman's side of the track. Various kinds of fixed-signal signs are shown in Figs. 118 and 119.

181. Danger-, Warning-, Award-signs, and Station-name Signs.—Highway-crossing signs must be placed at all public highway crossings. These are not required at farm or private crossings. The sign or signs should be placed not closer than 10 ft. to the nearest rail and must be set at right angles to the highway. If an unobstructed view permits the sign to be seen when approaching from either direction on the highway, one sign is sufficient. If there are two tracks or if the view is obstructed, a sign should be placed on each side of the track on the right-hand side of the highway approaching the track. If obstructions prevent these signs from being visible not less than 150 ft. along the highway, an additional sign should be placed 150 ft. from the crossing. As these signs cost from $5 to $10 it is considerably cheaper to place two or more additional signs at a dangerous crossing than to pay damages for one accident. When two railways are practically parallel and within 400 ft. of each other a lower arm bearing the words *Two Crossings* should be added to the highway-crossing sign. The lower part of the post of a highway-crossing sign should be painted black, the blades white, and the letters black. The letters of the main words should be of the Egyptian type and 9 in. high. Other letters should be half this height. Both sides of the board should be lettered. The blades should make an angle of about 50° with each other and should be about 8 ft. long. Different forms of highway-crossing signs are shown in Fig. 120.

At each end of a bridge a sign is usually placed to warn persons to keep off the bridge. At private crossings several railways place signs bearing some such inscription as *Not a Public Crossing; All Persons are Warned not to Trespass.* At other points where there is likelihood of persons trespassing on the railway property, trespass-signs should be placed.

As an encouragement to the section-crews, many railways place an award-sign in a conspicuous place on the section which the annual inspection shows to have been maintained in the best condition on that division during the previous year. These award-signs are much prized by the sectionmen and this system develops a competition between the crews of different sections. Two designs of award-signs are shown at (*F*) and (*G*), Fig. 121.

A station-sign, bearing the name of the station, is placed at each

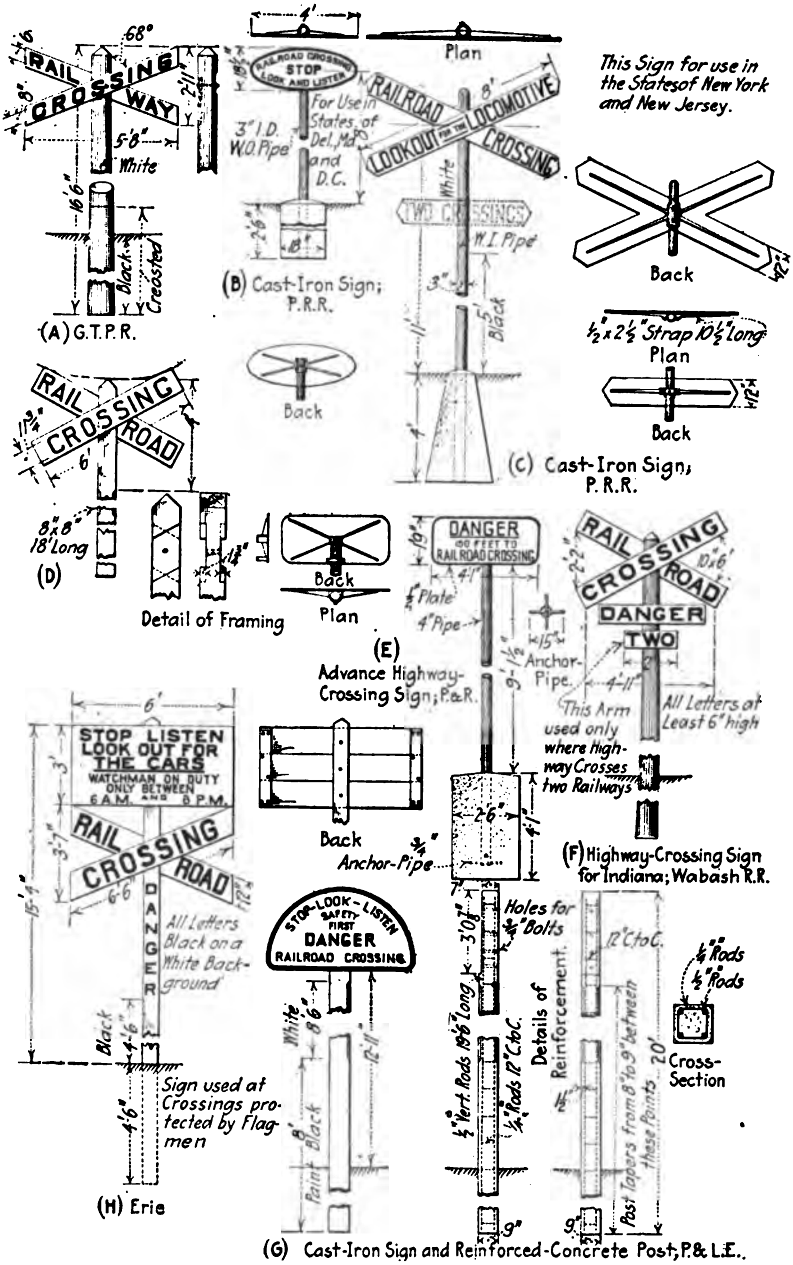
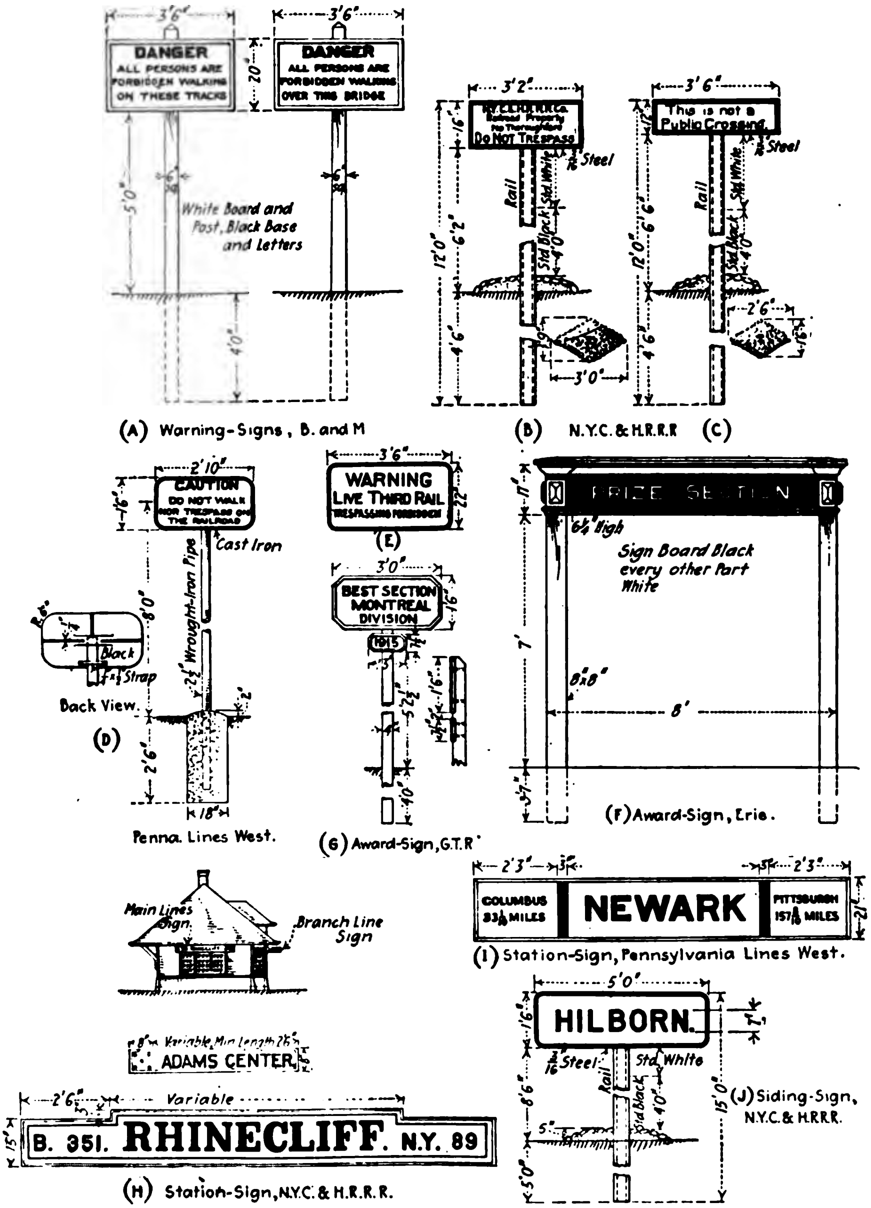

RAILWAY CROSSING
White
Black
Creosted
(A) G.T.P.R.
STOP
RAILROAD CROSSING
LOOK AND LISTEN
3" I.D. W.O. Pipe
For Use in States of Del., Md. and D.C.
Back
(B) Cast-Iron Sign; P.R.R.
Plan
RAILROAD CROSSING
LOOKOUT FOR THE LOCOMOTIVE
TWO CROSSINGS
White
W.I. Pipe
Black
This Sign for use in the States of New York and New Jersey.
Back
½"x 2½" Strap 10½" Long
Plan
Back
(C) Cast-Iron Sign, P.R.R.
RAIL CROSSING ROAD
8"x 8" 18' Long
(D)
Detail of Framing
Back
Plan
(E) Advance Highway-Crossing Sign; P.&R.
DANGER
100 FEET TO RAILROAD CROSSING
½" Plate
4" Pipe
Anchor-Pipe
This Arm used only where Highway Crosses two Railways
¾" Anchor-Pipe
RAIL CROSSING ROAD
DANGER
TWO
All Letters at Least 6" high
(F) Highway-Crossing Sign for Indiana; Wabash R.R.
STOP LISTEN
LOOK OUT FOR THE CARS
WATCHMAN ON DUTY ONLY BETWEEN 6 A.M. AND 8 P.M.
RAIL CROSSING ROAD
DANGER
All Letters Black on a White Background
Black
Sign used at Crossings protected by Flagmen
(H) Erie
STOP-LOOK-LISTEN
SAFETY FIRST
DANGER
RAILROAD CROSSING
White
Black
Paint
Holes for ¾" Bolts
¼" Vert. Rods 19'6" Long
¼" Rods 12" C to C.
Details of Reinforcement.
12" C to C.
Post Tapers from 8" to 9" between these Points
¼" Rods
½" Rods
Cross-Section
(G) Cast-Iron Sign and Reinforced-Concrete Post; P.& L.E.

FIG. 120.—Highway-crossing signs.

station and siding. Several forms of these are shown at (*H*), (*I*), and (*J*), Fig. 121. A name-sign may be placed on each end of the station-


(A) Warning-Signs, B. and M

(B) N.Y.C. & H.R.R.R (C)

(D) Penna. Lines West.

(E)

(F) Award-Sign, Erie.

(G) Award-Sign, G.T.R.

(H) Station-Sign, N.Y.C. & H.R.R.R.

(I) Station-Sign, Pennsylvania Lines West.

(J) Siding-Sign, N.Y.C. & H.R.R.R.

FIG. 121.—Warning-, award-, and station-signs.

building, perpendicular to the track; or the sign may be placed on the front and at the center of the building, facing the track; or a sign facing the track may be placed on a post at the side of the platform, at each end of the station. At a siding the sign should be placed at the point where business is transacted. On main lines the signs usually show the distance from each terminus in addition to the name, and the signs used by several railways in the West also give the elevation above sea level. The information given on these signs is for the convenience of patrons.

182. Fences.—Fences must be erected along the right-of-way at all places where there is danger of stock getting on the track. The post-and-wire fence has almost entirely taken the place of the post-and-board fence, though the latter is still used around parkings in station-grounds and as a railing for station-platforms. However, a metal post-and-chain or pipe fence similar to one of those shown at (*A*), (*B*), and (*C*), Fig. 122, is more serviceable at such places. A few railways use metal picket fences, (*D*) and (*F*), adjacent to stations and between tracks at stations where there are two or more tracks. Smooth, galvanized wire is the best for general fencing purposes. In the past galvanized fence-wire has proved very unsatisfactory due to the coating of the zinc being too thin and of an uneven thickness. The galvanizing of the wire of woven-wire fences must be done after weaving. The American Railway Engineering Association recommends the following three classes of smooth wire fences, the top wire of each being 4 ft. 6 in. from the ground.

> "A first-class fence shall consist of nine longitudinal, smooth, coiled, galvanized steel wires; the top and bottom wires shall be No. 7 gage; intermediate and stay wires shall be No. 9 gage. The spacing of the longitudinal wires shall be, commencing at the bottom, 3, 4, 5, 6, 7, 8, 9, and 9 in. The bottom wire shall be 3 in. above the ground, and the stay wires shall be spaced 12 in. apart.
>
> "A second-class fence shall consist of seven longitudinal, smooth, coiled, galvanized steel wires; the longitudinal wires and stay wires shall be No. 9 gage. The spacing of the longitudinal wires shall be, commencing at the bottom, 5, 6½, 7½, 9, 10, and 10 in. The bottom wire shall be 6 in. above the ground, and the stay wires shall be spaced 22 in. apart."
>
> "A third-class fence shall consist of four longitudinal, smooth, coiled, galvanized steel wires; the longitudinal and stay wires shall be No. 9 gage. The longitudinal wires shall be spaced 14 in. apart. The bottom wires shall be 12 in. above the ground, and the stay wires shall be spaced 22 in. apart."

When the roughness of the ground renders it impossible to properly stretch woven wire, the fence must be erected in the field. The same number of horizontal wires should be used as in the standard woven-wire fence. In wild cattle-grazing districts a stock-range fence, consisting of four horizontal barbed wires, can be used. A heavy, smooth wire or a plank is often placed at the top of a barbed-wire fence. End-posts should be set 4 ft. in the ground and intermediate posts should be set at least 3 ft. in the ground. Intermediate posts are set from 16½ to 33 ft. apart. End-, corner-, and gate-posts should be braced by having a

4- by 4-in. diagonal piece gained into the post near the top and into the next intermediate post near the ground. Corner- and gate-posts should be anchored by having two cleats gained and spiked to the post at right angles to the fence, one just below the ground surface and one near the lower end of the post. Intermediate posts set in depressions in the ground should be similarly anchored. If the posts are likely to be heaved by frost, the ends should be pointed to enable the posts to be driven down in the spring by the sectionmen. Where rock is encountered, intermediate posts may be set on 6-in. by 6-in. by 4-ft. sills braced on each side by 2-in. by 6-in. by 3-ft. diagonal braces, but not more than two adjacent posts should be so placed. Intermediate posts should be from 7 to 8 ft. long, and corner- and end-posts, 9 to 10 ft. long. Corner- and end-posts should

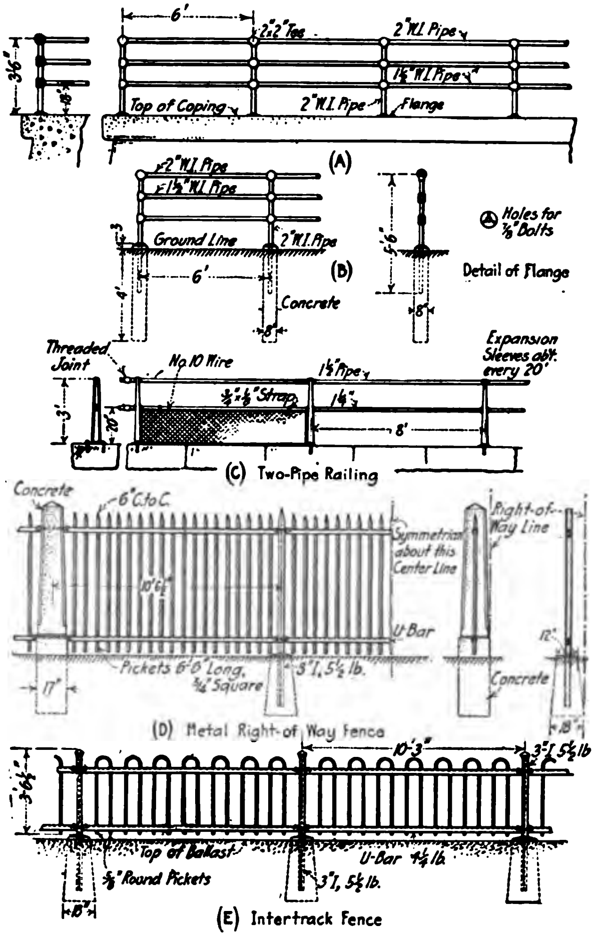
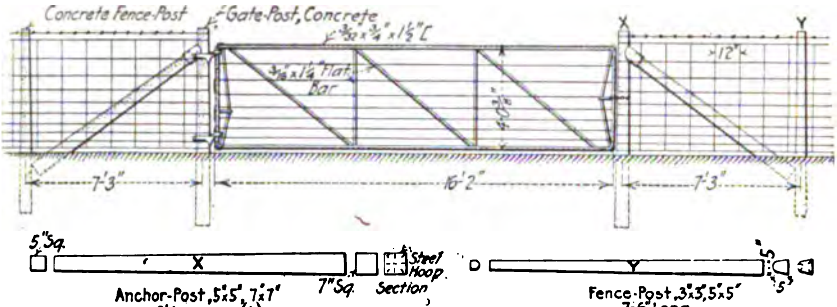
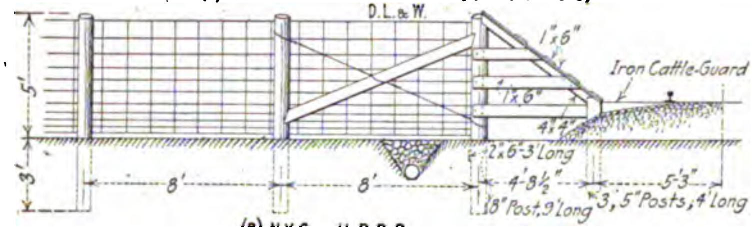


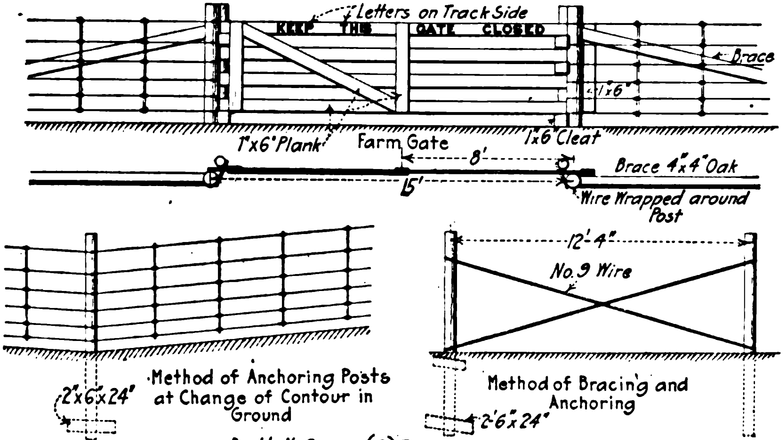
FIG. 122.—Metal fences.



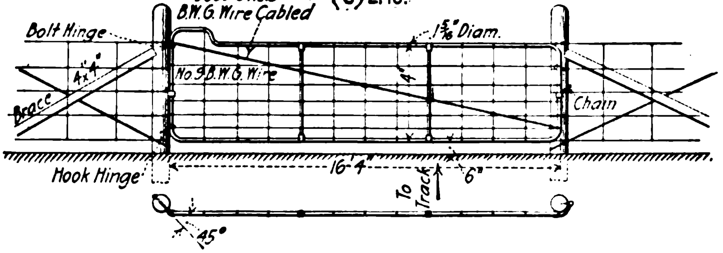
(A). Woven Wire Fence with Concrete Posts.



(B) N.Y.C. & H.R.R.R



(C) Erie.



(D) Farm Gate G.T.P.R.

FIG. 123.—Right-of-way fences and gates.

be not less than 8 in. in diameter at the small end. Intermediate posts should be not less than 5 in. in diameter at the small end, if round, or should have no face less than 5 in., if split.

On tangents the wires should be on the sides of the posts away from the track. On curves the wires should be placed on the sides of the posts away from the center of the curve. The width of farm gates depends on the size of agricultural machinery in use in the vicinity, but should not be less than 12 ft. Farm gates should open away from the track. Hinged gates are the best. These should be hung to close by their own weight. Several forms of right-of-way fences and gates are shown in Fig. 123.

A few metal and many concrete fence-posts are now being used. The concrete fence-posts used in right-of-way fences on the Delaware, Lackawanna and Western are shown at (*A*), Fig. 123. Concrete posts are made in a variety of sections. Tests conducted by the American Railway Engineering Association on reinforced-concrete posts having round, triangular, T-shaped, square, and semicircular sections indicate that the round section is the strongest.[1]

The cost of concrete fence-posts is from 20 to 50 cts. The post shown at *X* in Fig. 123, (*A*), cost 43 cts., and that shown at *Y* cost 18 to 20 cts. The cost of delivery was about 0.2 ct., digging the holes cost about 15 cts. each, setting posts 7.5 cts. each, and setting braces 7.5 cts. each. Concrete posts should be packed in straw or sawdust or have wooden strips between layers when being shipped. The cost of metal fence-posts is from $0.50 to $3 each. Wooden fence-posts cost from 10 to 25 cts. each; the cost of installation per post is from 5 to 10 cts. in earth and about 60 cts. in rock, and the cost of delivery is from 1 to 2 cts. each. A nine-wire fence with posts 16 to 20 ft. apart costs about 50 cts. per rod complete, in earth. From 1 to 5 per cent. of all wooden posts are destroyed by fire. The average life of all wooden fence-posts is about 12 years.

183. Wing-fences and Stock-guards.—A wing-fence is a cross fence extending from the right-of-way fence to the edge of the track, where it connects with the apron of a stock-guard. A wing-fence is shown at (*B*), Fig. 123. Fig. 124 shows the general plan of cattle- or stock-guards and wing-fences at a highway crossing.

A stock-guard is intended as a barrier to prevent the passage of stock along the track. It should be of such length and design and so constructed as to effectually prevent the passage of stock; reasonable in first cost; durable; easily and cheaply applied and repaired; so constructed as not to endanger employees whose duties require them to walk along the track; not rattle during the passage of a train; and should have no projection which might catch dragging train-rigging. Stock-guards are of two kinds, namely, pit and surface guards. Pit-guards consist of an open pit or culvert extending across the track and over which the rails are carried on longitudinal sills, the ties being omitted. The pits are from 2½ to 4 ft. deep and from 5 to 10 ft. wide. They effectually prevent the passage of stock but are dangerous to the stock and to persons walking on the track, especially at night. The open pit stock-guard is now largely obsolete.

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[1] Bulletin 172, Am. Ry. Eng. Assn., page 495, Table 8.

Surface stock-guards are made either of wood or metal and usually consist of three or more sections of sharp-edged or toothed slats. The slats are held in place by fillers and both are fastened to a frame which in turn rests on and is fastened to the ties. The corrosion of steel guards is rapid, so that wood guards are used mostly. The stock-guard is connected to the wing-fences on each side by a triangular apron (crow's foot) or rectangular apron set parallel to the track and at an angle of about 45° with the horizontal. The apron may be symmetrical about the wing-fence or may be all on the side of the wing-fence away from the highway, as shown at *A*, Fig. 125. Metal guards are objectionable on track carrying heavy track circuits. Guards for single track are made in either three or four sections. If composed of three sections the section between the rails is about 4 ft. 5 in. wide and the sections on the outside of each rail are about 2 ft. 6 in. wide. If four sections are used each section is made the same width, which is about 2 ft. 2½ in., so that all sections are interchangeable. Some metal guards consist of metal plates having triangular pieces punched and bent up to form spikes. A guard made of flattened old boiler flues is shown at (*C*).

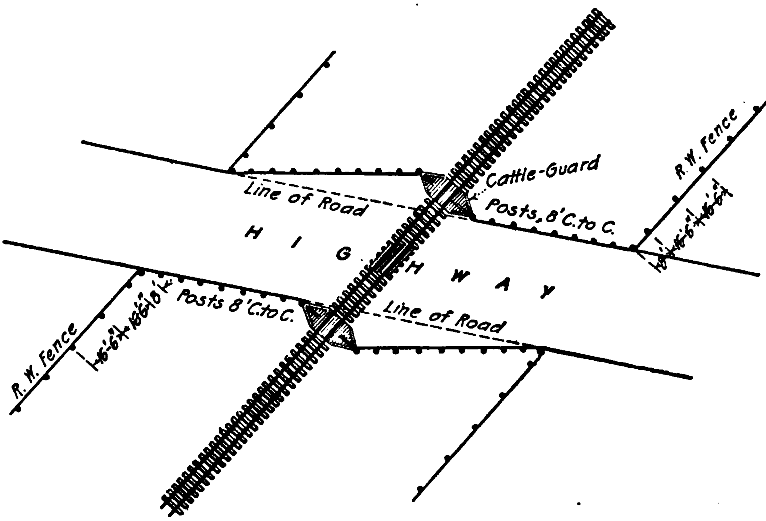
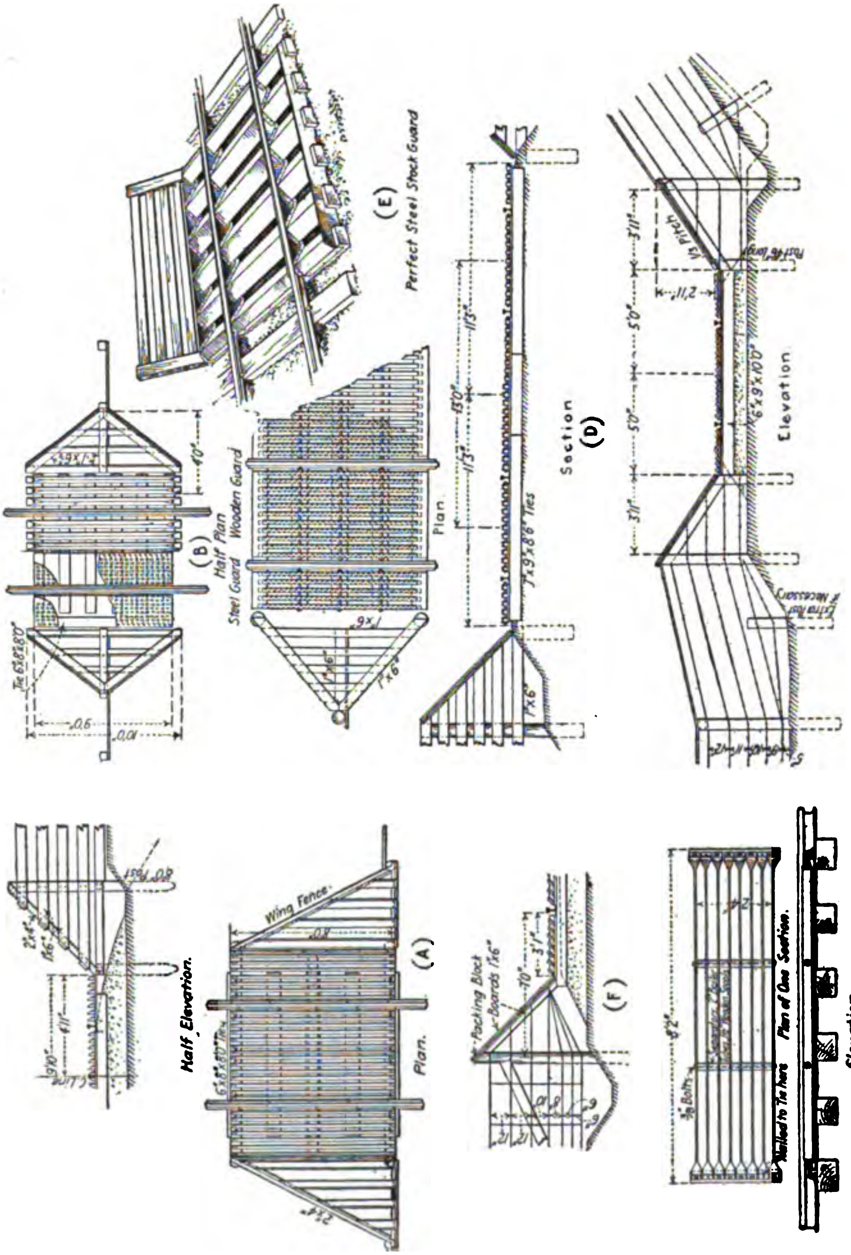


FIG. 124.—General plan of wing-fences and cattle- or stock-guards.

Some stock-guards have the slats laid parallel to the ties. This arrangement has the advantage that there is less danger of dragging train-rigging being caught by the guard. Many trackmen consider a guard

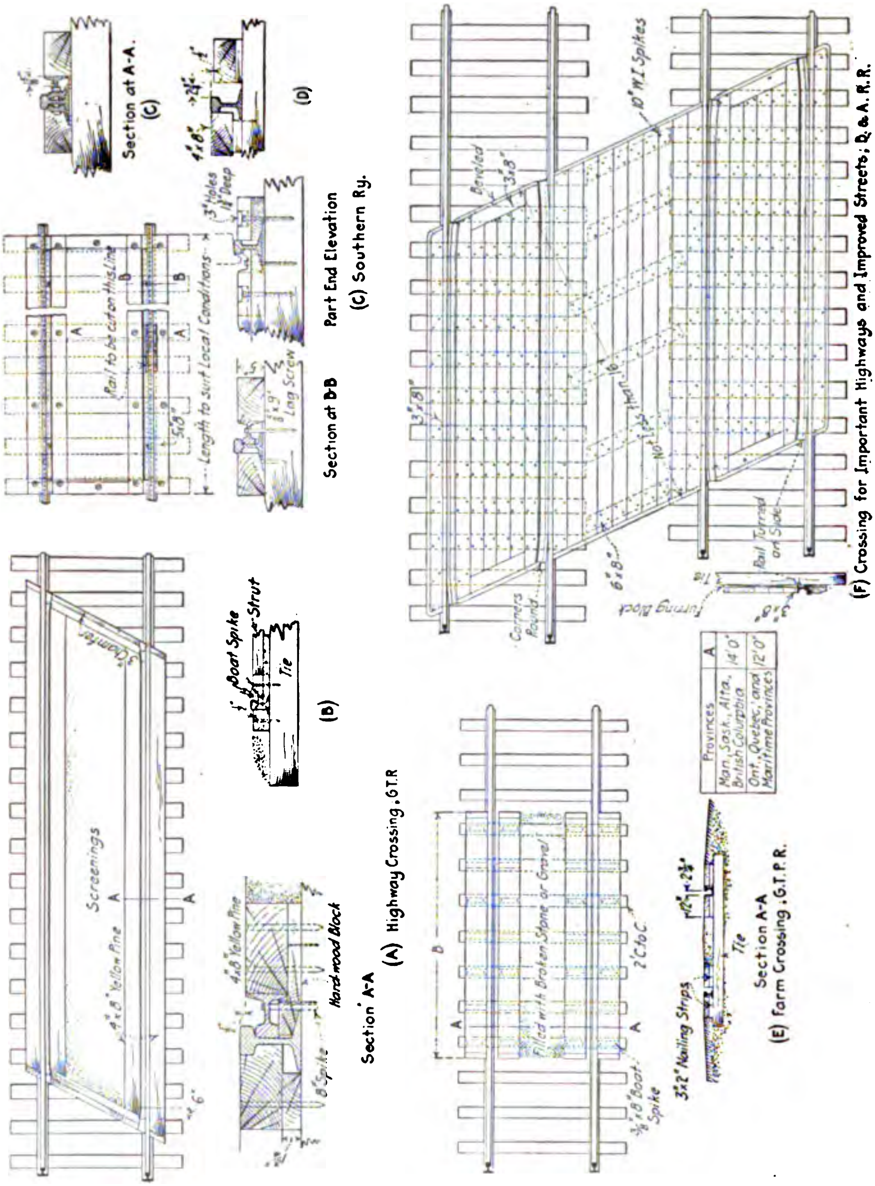


(C) Flue Stock-Guard

FIG. 125.—Stock-guards.

of this type, which has broad slats with a slope of about 45°, to be more effective in turning unruly animals than a guard in which the slats are parallel to the rails. However, the latter form is most commonly used. Several forms of surface stock-guards are shown in Fig. 125.

184. Highway Crossings.—Where public and private roads cross the track the space on each side of and between the rails must be filled about level with the top of the rails, each rail must be protected on each side from the wheels of road vehicles, and a flangeway must be provided



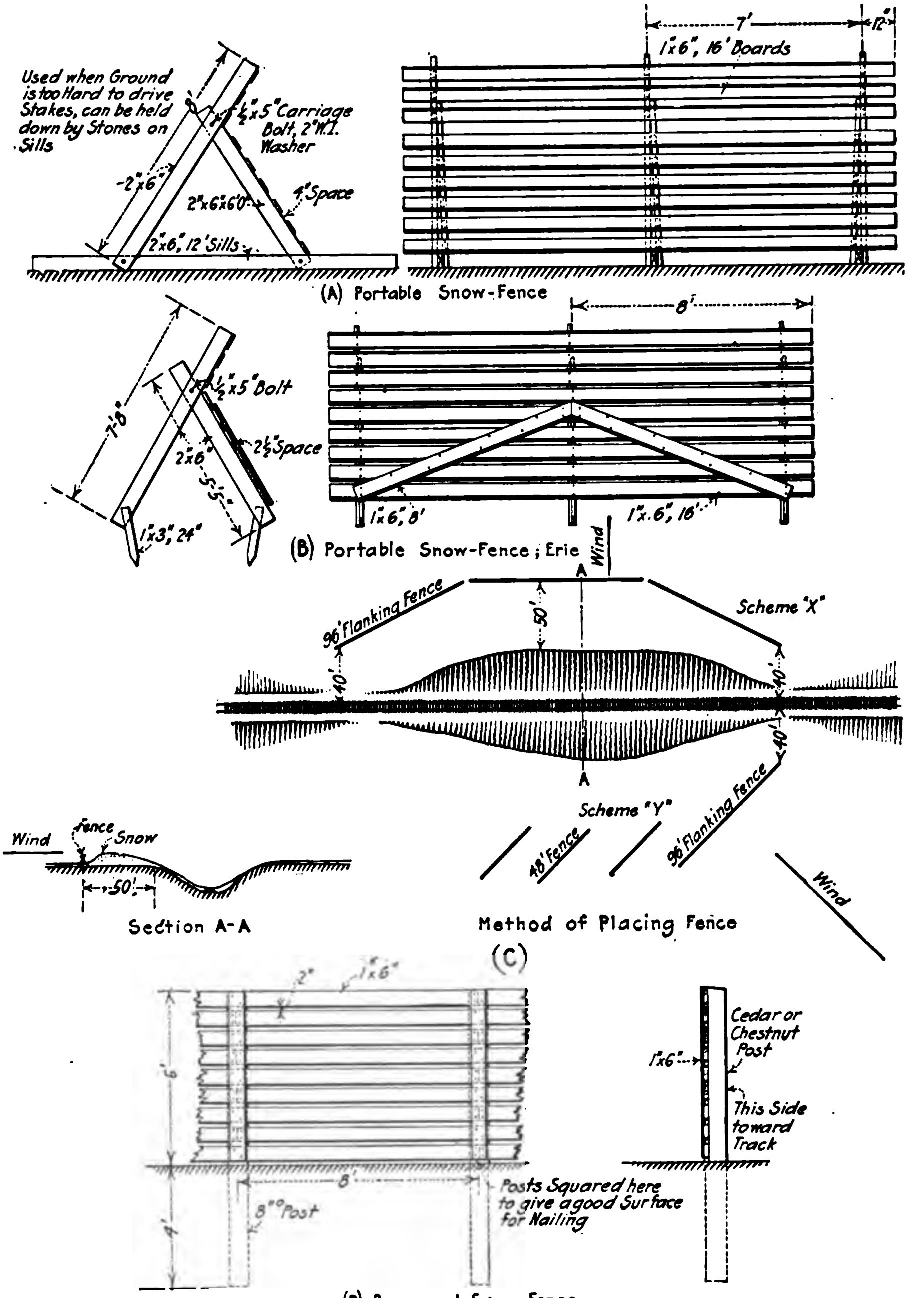
Provinces	A
Man., Sask., Alta., British Columbia	14'0"
Ont., Quebec, and Maritime Provinces	12'0"

FIG. 126.—Highway and farm crossings.

inside each rail. In paved streets the pavement is brought up to the rail on each side, a flangeway being provided by using a guard-rail or a special guard bolted to the rail-web, as shown in Figs. 56 and 70. At highway crossings the rail should be protected on the outside by a heavy plank. The flangeway may be provided in the following ways: (1) An ordinary guard-rail may be placed inside the track-rail. This requires the use of a filler block between the main rail and guard-rail. (2) A second-hand rail may be turned on its side and placed with its head against the web of the main rail, as shown at (*A*), (*C*), and (*F*), Fig. 126. This is one of the commonest and most satisfactory methods employed. (3) The inside plank may be kept away from the rail, as at (*D*), or a grooved plank may be used, as at (*B*). For streets and important highways the space between the rails, and between tracks if there are more than one, should be fully planked, as shown at (*F*). For less important highways the method shown at (*A*) is sufficient, and the method shown at (*E*) is all that is required at farm crossings. The space inside the guard-rails or planks should be filled to about the top of rail with broken stone or gravel or the best available local material, and should be given a slight crown parallel with the track.

The approach to the crossing should be properly graded and the gradient should not be over 5 per cent. for both cut and fill. In cuts the road should be graded level for the length of a horse and wagon, if practicable to do so. The ballast should be kept at least an inch below the bottom of the planks to prevent heaving in winter, and the planks must be watched at all times to see that they do not project above the track or offer any sharp edges or corners which might catch dragging train-rigging. The width of the crossing depends on the importance of the highway, and is 12 or 14 ft. for farm crossings and unimportant country roads, about 16 ft. for main highways, and 20 ft. for town and village streets. The thickness of planks varies from 3 to 5 in. Fig. 126 illustrates several standard designs for crossings and the methods of providing a flangeway.

185. Snow-fences.—Snow is carried by the wind close to the surface of the ground. When the wind encounters any obstruction which causes eddies or breaks its velocity it deposits all or part of its load of snow. As the wind blows across the railway cut, eddies are set up in the air current which cause the snow to be deposited in the cut. Snow-fences are used to form artificial eddies on the windward side of the cut. They must be at a sufficient distance to cause the snow to deposit between the snow-fence and the cut. In general, snow-fences are of two kinds, a tight fence and an open fence. Either of these may be made as a permanent fence or a portable fence. A tight fence of proper height causes the drift to form principally to windward. Hence tight fences can be placed near the edge of the cut. The distance between the fence and



(A) Portable Snow-Fence

(B) Portable Snow-Fence; Erie

(C)

(D) Permanent Snow-Fence

FIG. 127.—Snow-fences.

drift depends upon the height of the fence, the wind velocity, the width of openings between the boards of the fence, the direction of the wind, and the character of the snow. As several of these are variable and depend upon local conditions the portable fence is the best for general purposes, although where conditions permit, a permanent snow-fence within the right-of-way is the most economical. Permanent snow-fences placed 50 ft. or less from the center of the track should be of close construction. For a greater distance the space between boards should be increased until at 100 ft. 50 per cent. of the fence should be open. The height of permanent fences depends upon the amount of snow, but should not be over 10 ft.[1]

Portable fences should be set on the windward side of the track, perpendicular to the direction of the prevailing wind. Sometimes several lines of fences are necessary. These are set from 75 to 100 ft. apart. In northern climates portable fences should be erected soon after November 1, and should be removed about April 1. In rocky countries rough stone walls are sometimes erected as right-of-way fences. These also act as permanent snow-fences. Hedge fences also are used occasionally and make a satisfactory permanent snow-fence. The portable snow-fence is usually some form of a collapsible A frame which can be taken down, folded, and piled. When the ground is too hard to drive stakes the two legs of the frame are fastened to a sill which rests on the surface of the ground as at (*A*), Fig. 127. It is preferable to fasten each leg to a stake, as shown at (*B*). Two schemes for placing portable snow-fences are shown at (*C*), and a permanent snow-fence is shown at (*D*). The boards on a permanent fence are usually placed horizontal but may be vertical or diagonal.

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[1] Manual, Am. Ry. Eng. Assn.

CHAPTER XIV

ACCESSORIES TO TRACK

186. Clearances.—As a basis for the inside dimensions of bridges, tunnels, etc., and for the location of various structures at the side of, below, and above the track, each railway must adopt standard structural and equipment clearance limits. Equipment clearance lines fix the maximum outside dimensions of the rolling-stock. Structural clearance lines fix the minimum horizontal and vertical distances of any permanent object from the track. These are also necessary to shippers, as well as to the railway, in order to know the size of the largest object that can be transported on open cars and safely clear all structures adjacent to the track. The clearance limits of almost every railway have gradually increased until little room now remains for increase, without radical changes in the dimensions of important structures. The expense of this would be almost prohibitive on many railways.

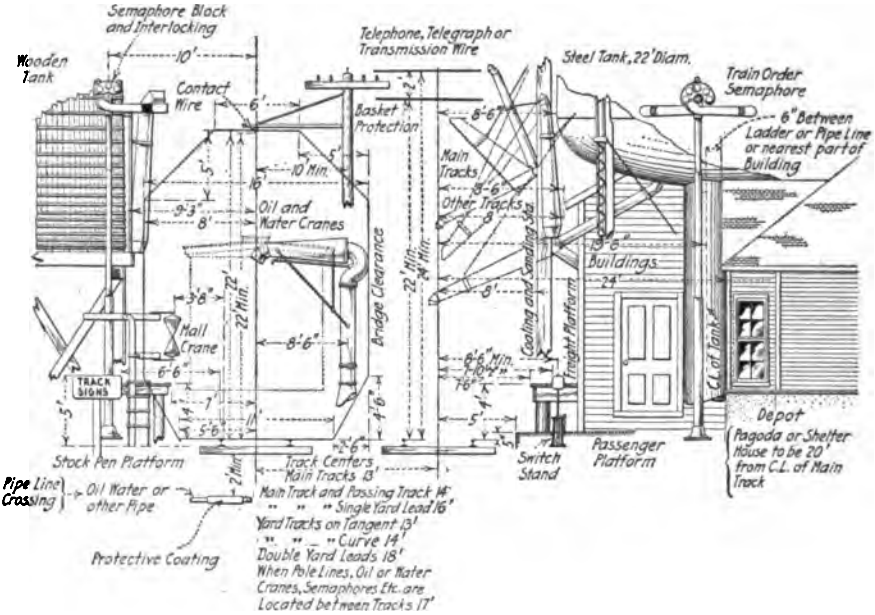


FIG. 128.—Clearance diagram; K. C. S. Ry.

It is the duty of section-foremen to see that no structures, materials, or tools are placed at any time within the minimum clearance limits of the railway. Section forces must be very careful never to raise the surface of track in tunnels, in front of coal-chutes, water-cranes, station-platforms, or where there are any overhead crossings. It is also the duty of bridge-inspectors to see that the clearances at all structures are not changed. The overhang of cars and the effect of superelevation make the actual clearance lines on curves different from those on tangents. Fig. 128 is a composite drawing of the clearance limits of the Kansas City Southern Railway.

The American Railway Engineering Association recommends the following minimum clearance limits for structures:

> A uniform width of 11 ft. from base of rail to a point 1 ft. above the top of rail, from which point it will widen out uniformly to 15 ft. at a point 4 ft. above top of rail. It remains 15 ft. wide to a point 16 ft. above top of rail, where it narrows uniformly to a width of 7 ft. and a clear height of 22 ft. above top of rail. In electrified zones requiring overhead high-tension conductors a clear height of 25 ft. above top of rail is desirable.

187. Water-tanks.—Railway water-tanks are usually constructed of wooden staves with iron or steel hoops, though many tanks of large capacity are built of riveted steel plates, and a few reinforced-concrete tanks have been built. Wood is preferable for tanks of small capacity and for tanks used for temporary purposes. A wooden tank can be taken down and re-erected with little difficulty in a new location. The life of wooden tanks depends on the kind of lumber used, whether the tank is kept full, whether the water is allowed to freeze, painting of the outside, etc., and averages about 20 years. The life of the hoops is often only about half that of the tank. The spacing of the hoops must be determined by computing the water pressure at all depths of the tank. The capacity varies from about 25,000 gal. to 100,000 gal., but a few tanks with capacities exceeding 500,000 gal. have been built for railway purposes. Reinforced-concrete water-tanks are an innovation in railway service, though the first application of reinforced concrete was to a vessel for holding water. The advantages to be gained by using reinforced concrete for water-tanks are durability and low maintenance cost. At present it appears that the advantages are offset by the disadvantages, which are greater first cost, poor materials and workmanship, difficulty of waterproofing the concrete, shrinkage and stretch of the concrete, unsightliness, and effect of frost upon the saturated concrete. These tanks are either built as standpipes or as elevated tanks on concrete columns or towers.

Water-tanks may be supplied by gravity; or by steam, gasoline, or electric pumps, operated by the railway; or by municipal water supply. Steam power will be the most economical when the pumping station is near a steam plant maintained for other purposes, such as shops, and when 100 lb. of coal delivered at the pumping station is cheaper than 1 gal. of gasoline delivered at the gasoline storage tank. Where the reverse conditions obtain, gasoline will be the most economical. Electric power will be most economical if the pumping station is adjacent to a power line of the railway, as in electrified territory or where alternating current is used for signal purposes. A 48,000-gal. wooden water-tank is shown in Fig. 129, and a 100,000-gal. steel water-tank is shown in Fig. 130.

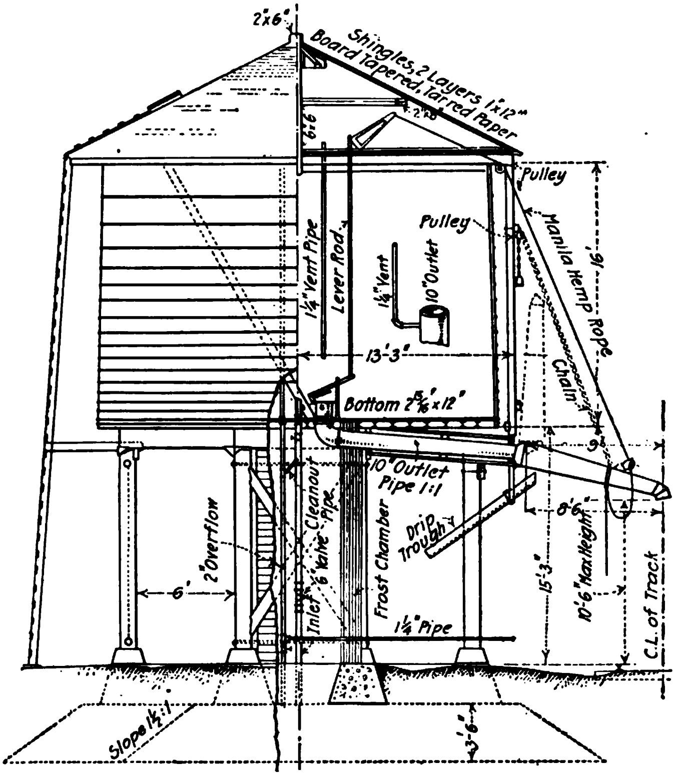
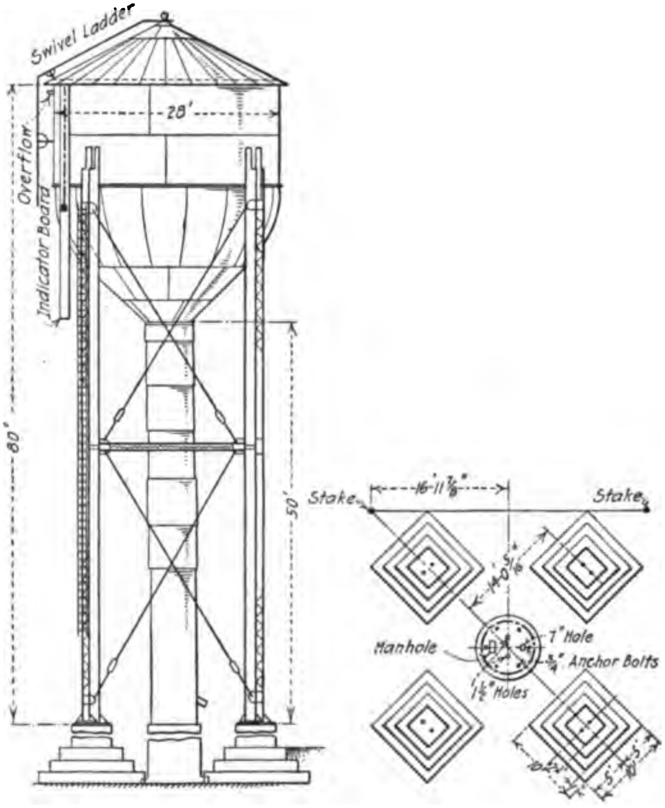


Fig. 129.—48,000-gallon wooden water-tank.

188. Water-columns.—When it is unnecessary to provide a storage supply, as where the railway gets its water from an adequate municipal supply, or where it is necessary for the railway to maintain a large storage tank or reservoir, a water-column is more economical than a water-tank. A water-column also has the advantage that it can be located where space is limited, as for instance between tracks, and in such a position can serve two tracks. A water-column consists of a vertical pipe with a horizontal spout at the top, as shown in Fig. 131. The valve gear is in a pit below ground at the base of the column. A lever at the top of the column extends out over the track. When an engine is to take water, the fireman pulls down on the lever and through other connecting levers this opens the valve.

189. Track-tanks.[1]—In order to maintain long, fast passenger-runs it is desirable for the engine to take water without stopping. Track-tanks were invented for this purpose and in the past have been used mostly in passenger-service. The serious objections to stopping and starting heavy freight-trains have brought about the adoption of track-tanks also for freight-service. A track-tank is a shallow metal trough placed on the ties between the rails. When an engine desires to take water from the tank a scoop on the tender is lowered into the trough and the speed of the train elevates the water into the tender through an inclined pipe. The troughs are from 6 to 7½ in. deep and from 19 to 29 in. wide, and usually are dapped into the tie. The maximum dap should not exceed 2¼ in. The length of the tank depends on the distance



Elevation Foundation Plan

FIG. 130.—100,000-gallon steel water-tank.

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[1] See Vols. 12 and 14, Proceedings, Am. Ry. Eng. Assn.

between tanks, the size of the tank, and the size and dip of the scoop. The length is from 1200 to 2600 ft., averaging about 2000 ft., and the tanks should be about 40 miles apart. Track-tanks should be located on tangents—though they can be operated on curves up to 3°—and at places where the train can have a speed of about 25 miles an hour. The first track-tank appears to have been installed on the London & North Western Railway, of England, about 1857. The first track-tank in America was installed in 1870 by the New York Central.

Track-tanks introduce several unusual maintenance conditions requiring special attention. From 20 to 50 per cent. of the water is splashed out on the track and wasted. Elaborate draining is necessary to dispose of this water before it reaches and softens the roadbed, or in the winter, before it freezes and heaves the track. Also some means must be taken in cold weather to prevent the water from freezing in the tanks. Drainage is accomplished by paving the top of the roadbed with large stones upon which a good depth of broken stone ballast is placed, by placing deep subdrains between the tracks, and by providing numerous cross drains to convey the water from the longitudinal drains to the side of the track. The New York Central installs surface box drains every 50

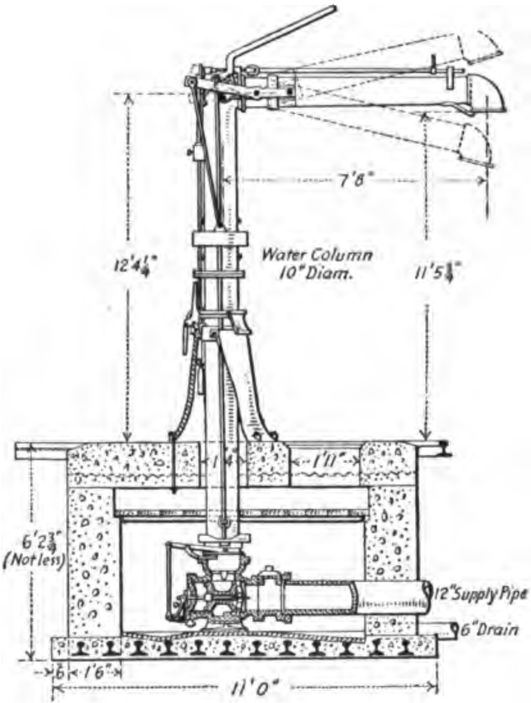
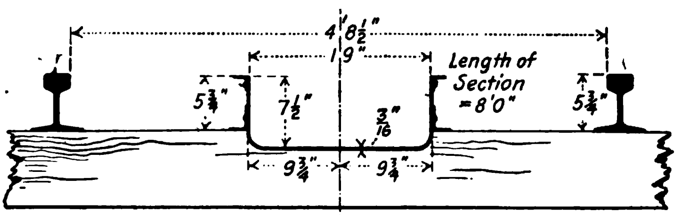


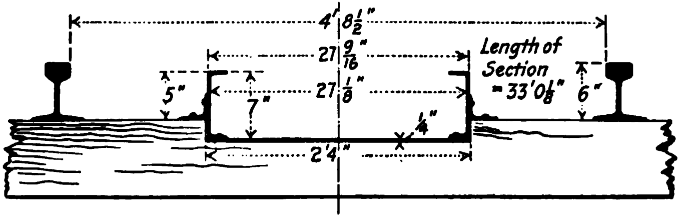
Fig. 131.—Water-column.

ft., longitudinal graded trenches filled with cobble stones between the tracks, and transverse tile subdrains intercepting the longitudinal drains every 100 ft. This method has proved satisfactory in quickly disposing of the water.

Two systems are used to heat the water in winter. In modern installations one or more water-mains extend nearly the length of the tank and water is supplied to the tank at several points from branch connections. The supply is controlled by automatic valves actuated by a change in level of the water. The number of inlets required depends on the interval between trains. A trough 1400 ft. long and 27 in. wide requires from 4 to 6 min. to fill from 3 inlets. In the direct-heating system steam-pipes extend the length of the troughs, and branch pipes, at intervals of about 33 ft., discharge steam into the bottom or sides of the trough. In the circulatory system the ends of several sections of pipe of about 4 in. in diameter are connected to the trough. A circulation is maintained through the pipes, and the water is heated by injecting steam at the inlet to each section of the pipe. The sections of pipe are 333 ft. long in recent installations of tanks 2000 ft. long on the Lake Shore and Michigan Southern. The direct heating system appears to be the most economical as it requires less pipe, there is less loss of heat, and less heat is required. The majority of track-tanks used hitherto have been made of sections of metal troughs bolted together. The earlier tanks of this kind were made of cast iron, but sheet steel or sheet iron, bent to the desired form, is now generally used. The New York Central has recently adopted a standard trough built up of two channels with flanges turned in, which form the sides, and a flat plate riveted to the lower flange of each channel,



L.S. & M.S. Ry.



N.Y.C. & H.R. RR.

Fig. 132.—Track-tanks.

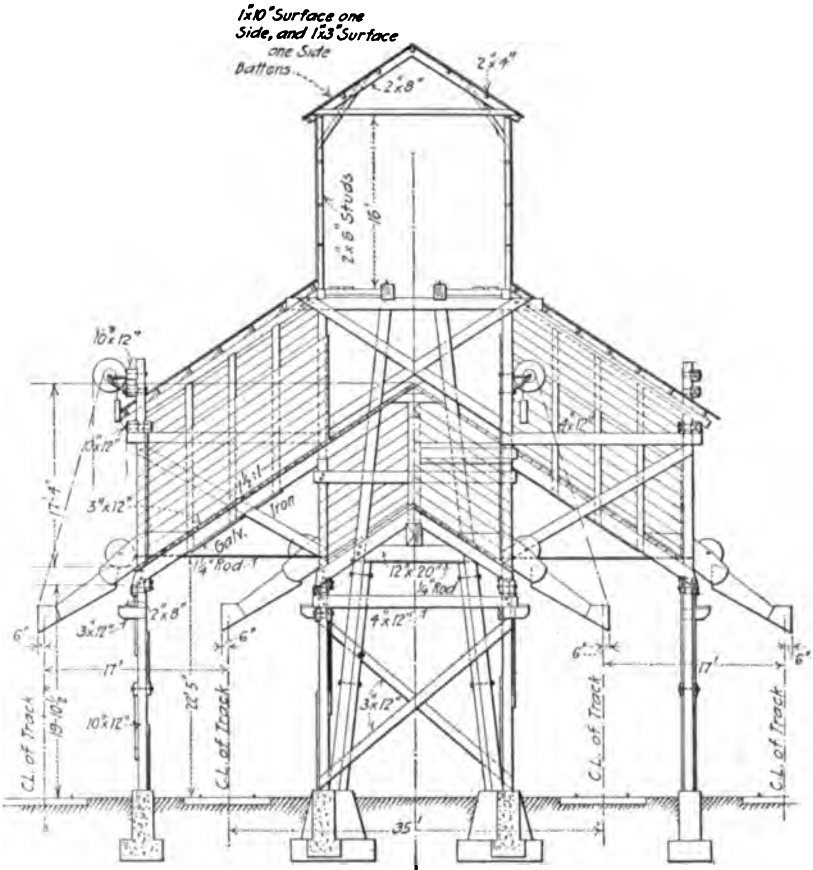
which forms the bottom. This design has several advantages over the one-piece cross-section. The first cost is less, and the bottom, where the principal wear of a track-tank occurs, can be renewed separately. These two types of troughs are shown in Fig. 132. An inclined plate from 7 to 10 ft. long must be placed on each side of each end of the trough to lift the scoop if it is lowered too soon or not raised soon enough. At Wilmore, Pa., the Pennsylvania Railroad has a track-tank 2600 ft. long in each of the two east-bound tracks. Over 2,250,000 gal. of water are used in 24 hr. at this water station, which is probably the largest amount of water consumed at any railway water station in America.

190. Coaling Stations.—The railways of the United States consume about 120,000,000 tons of coal per year. The labor cost of placing the coal in the tender of the locomotive increases the final cost per ton to the railway from 0.1 to 5 per cent. One cent saved per ton would mean a yearly saving of $1,200,000. The labor cost depends on the method used in operating the coaling station and varies considerably for different methods of handling the coal. In considering the type of coaling station to be used at any point several things must be considered: ground room, especially around busy terminals, is important; the first cost of the plant together with the relative expense of operating and maintaining it; the type of plant best suited for traffic conditions at that place; and the character of cars in which coal is received. The tendency is to adopt plants which can be operated by a minimum number of men.

Coaling stations may be classified as follows: (1) Chutes. (2) Clam-shell buckets. (3) Mechanical. (4) Miscellaneous. There are an endless number of coaling stations in use with various modifications depending entirely on local conditions. Where the amount of coal is small the coal is usually shoveled from the car directly to the tender or from the car to an elevated platform and then to the tender.

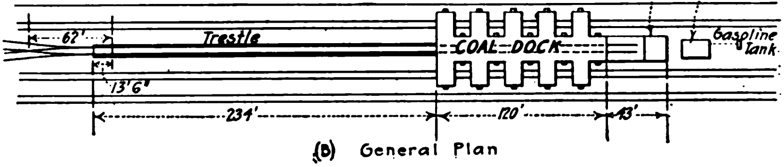
Coal-chutes usually consist of an inclined track leading to a level trestle from 12 to 45 or 50 ft. above the ground, at the side of which bins are constructed. The entire structure should be covered with a roof. If the incline is not over 5 per cent. the cars can be pushed up by a locomotive. If space is not available a short, steep incline having about a 20 per cent. gradient can be used and the cars hauled up by a stationary engine and cable. The coal is either shoveled from the car to the bin or, if dump cars are available and the trestle is made higher, the coal can be dumped into the bins by gravity. When a locomotive wishes to take coal a chute carries the coal from the bin to the tender. If ground is available the capacity of a plant of this kind can be made to supply from one to four engine-tracks. A chute coaling station or "coal dock" for supplying four engine-tracks is shown in plan and elevation in Fig. 133. The approach trestle is on a 20 per cent. gradient. The cars are hauled up by a cable and the coal falls by gravity into the bins. The trestle has ten

12-ft. sections and has a capacity of 990 tons. After the first 10 years the yearly cost of maintenance of wooden coaling stations is about 10 per cent. of the first cost.



Cross-Section through Outer Pocket | Cross-Section through Inner Pocket

(A)



(B) General Plan

Fig. 133.—Chute coaling station for four engine-tracks; N. P. Ry.

Coal-trestles are used in coal-storage yards, and frequently at coaling stations when locomotive cranes are used for coaling engines. The coal-cars are run up the trestle and the coal is dumped by gravity upon piles below.

Locomotive cranes and clam-shell buckets are used on several large railways. They may be used to transfer the coal from the pile or car to an elevated bin from which the coal drops by gravity to the tender, or they may transfer the coal directly to the tender. Where the number of locomotives to be coaled is not large this is an economical method of handling the coal. A plant of this kind requires considerable space, the coal is exposed to the weather and may deteriorate in value, and there is danger of spontaneous combustion.

The general features of mechanical coaling stations are the dumping of coal from self-cleaning cars into a pit, which in some plants contains a breaking device; elevating the coal from the pit to the storage bin located some distance above the track; weighing the coal; and delivering the coal from the bin, through a chute, to the locomotive. It is desirable that the weight of coal given a locomotive be known accurately so that the consumption per ton mile can be determined, but in the past this seldom has been done. The breaking device may be a mechanical crusher, or bars against which the coal falls. The coal is then raised to the bin by a continuous bucket conveyor or by elevators. Mechanical coaling stations are constructed of wood, metal, or reinforced concrete. A 200-ton capacity mechanical coaling plant with reinforced-concrete coal-pocket built by the National Transcontinental Railway is shown in Fig. 134. In general, where the amount of coal to be handled is from 100 to 250 tons per day a derrick and bucket plant, a locomotive crane, or a clam-shell bucket and chute combined, are advisable. Where more than 250 tons

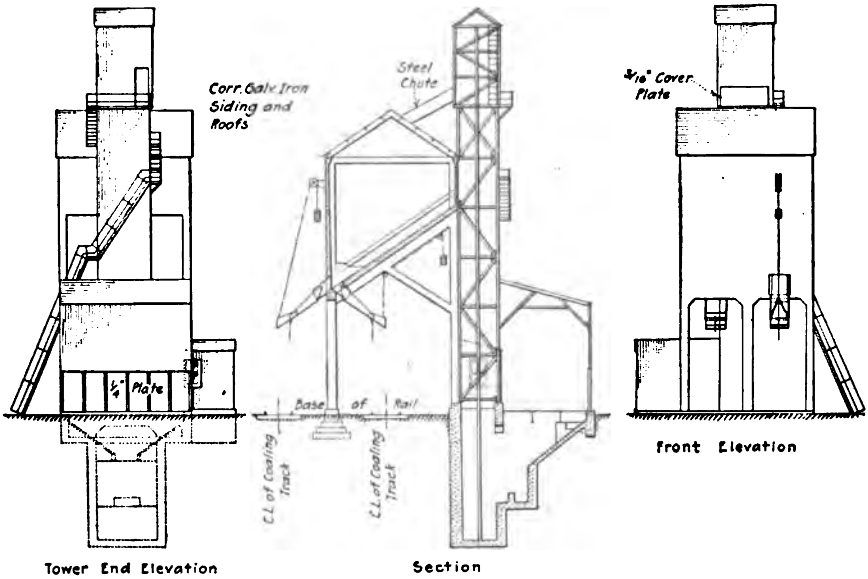


FIG. 134.—Mechanical coaling station; N. T. R.

per day are handled a trestle and chute or a mechanical plant are most economical. Every coaling station should have a storage capacity sufficient for several days supply. At many plants the coal must be stored in cars; otherwise an additional handling of the coal is necessary. Both are uneconomical.

191. Sand for Locomotives.—At engine terminals an adequate provision should be made for supplying dry sand to locomotives. Mechanical coaling stations usually include facilities for drying, elevating, storing, and supplying sand to the locomotives. The average locomotive sand box holds from 6 to 10 cu. ft. of sand. The green sand is usually unloaded in piles or bins near the coaling station, the sand is dried in a sand-drying stove and the dry sand is placed in an elevated hopper from which it is drawn by gravity through a spout to the sand-box of the engine.

192. Ash-pits.—The ash-pans of the average freight-engine contain from 1 to 2 cu. yd. of ashes at the end of a run. The design of the ash-plant will depend on the number of engines handled per day. At a terminal handling 100 engines in 24 hr., from 100 to 200 cu. yd. of ashes must be handled. The most satisfactory ash-plant for handling more than fifty engines per day consists of a pit with engine-tracks on one or both sides. One rail, or both rails, of the engine-track is carried on metal piers over a shallow pit called the shoveling platform. Outside the pier the pit is made from 2 to 8 ft. deeper to carry a depressed track. If proper drainage of the depressed track can be secured and a large volume of ashes must be handled, the pit-track should be depressed enough to bring the tops of gondola-cars slightly below the shoveling platform. A few improved pits have been constructed in which the shoveling platform is sharply inclined so that the ashes slide by gravity or can be washed into the ash-cars. The entire construction of the pit must be fireproof. Concrete is not satisfactory for the surfaces which come in contact with the hot ashes. Metal columns, fire-brick for the walls and floor of the shoveling platform, and concrete for the depressed track are satisfactory materials. The time required to clean the ashes of a small engine is from 10 to 15 min. A medium-sized engine requires about 30 min. and a large engine about 45 min. If the ash-pans are frozen, the time required may be several times longer. The pit may serve one or two engine-tracks and may be made large enough to accommodate from one to three engines at a time on each track. Under normal conditions the labor cost of cleaning is from 18 to 30 cts. per engine and the cost of handling ashes is from 3 to 5 cts. per cubic yard. Figure 135 shows an ash-pit with depressed track and one engine-track.

193. Track-scales.[1]—Track-scales are of two general types, named after the inventors, the Sampson and the Fairbanks. The Sampson

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[1] 1913 Proceedings, Am. Ry. Bridge and Building Assn.

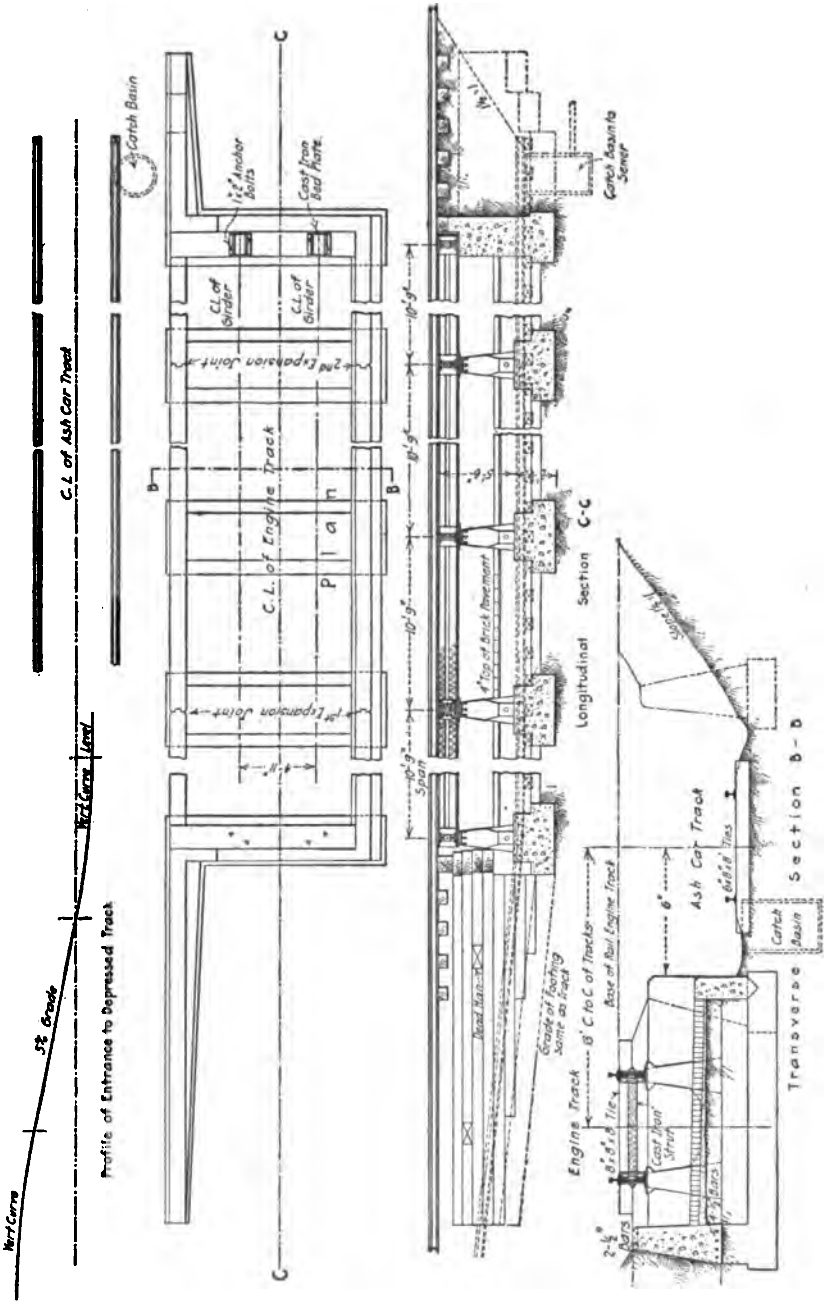


FIG. 135.—Ash-pit; C. M. & St. P. Ry.

type has no cross levers, but instead has round levers which transmit the load to the extension levers by torsion. The main or extension levers do not transmit their load from one to the other but transmit it to a longitudinal shaft parallel to the extension levers. The Fairbanks system consists of several sections, usually four or more, each comprising a pair of main levers which run at right angles to the track. The load is transmitted to the main-lever bearings, is then carried to the extension levers, which run parallel to the track and connect with one another, then through these to the butt of the transverse lever which transmits the load to the scale-beam. Figure 136 shows a 50-ft., 125-ton track-scale of the Fairbanks type. The chief object to be accomplished in any design is to allow the load to be transferred to the weighing platform with a minimum disturbance to the mechanism of the scale, and especially to the delicate knife-edges. A worn or broken knife-edge destroys the multiplication at that point and produces a constant error. It is unnecessary to have the sensitiveness of scales greater than 100 lb. In checking the weight of a car as given by different scales, a difference of 200 lb. above or below is usually considered a check, since wind may affect the weight by as much as 200 lb. The length of scales in use varies from 40 ft. to 67 ft., the longer scales being used for gravity switching. The track-rails should slightly overhang the weight-bridge so that the weight is gradually applied to the scale. Many recent installations provide no dead rails, necessitating all cars and engines moving on the scale-track to pass over the scale. This does not appear to injure modern high-capacity scales, though the rules of most railways forbid switching or the passage of locomotives over the scale. The Streeter-Amet weight recorder is commonly spoken of as a weighing and recording device, but in reality it is merely a mechanical device which automatically records the weight of an object on the scales. The counterweight on the scale-beam must be actuated by the weighmaster, who must also look after the tape or cards upon which the weight is automatically stamped. The cost of scales installed is from $2000 to $8000, depending on length, capacity, and character of foundations. A 40-ft., 100-ton scale on the Florida East Coast Railway cost $2407. A 67-ft., 200-ton scale on the Pittsburgh and Lake Erie Railroad, at Glassport, Pa., cost $8072.

The track-scale in a large measure determines the revenue of the railway. Hence it is very important that at all times it be kept in the very best condition and be frequently tested to ascertain its condition and accuracy. The testing is usually done by a scale-inspector, who reports to the bridge engineer. A test car of known weight is used for testing the accuracy of the scale. Some railways run the test car over the scale daily. The scale should be inspected at least once a month by an expert. The most common causes of incorrect weight are carelessness of the weighmaster in balancing the scale or in allowing another car to be partly on

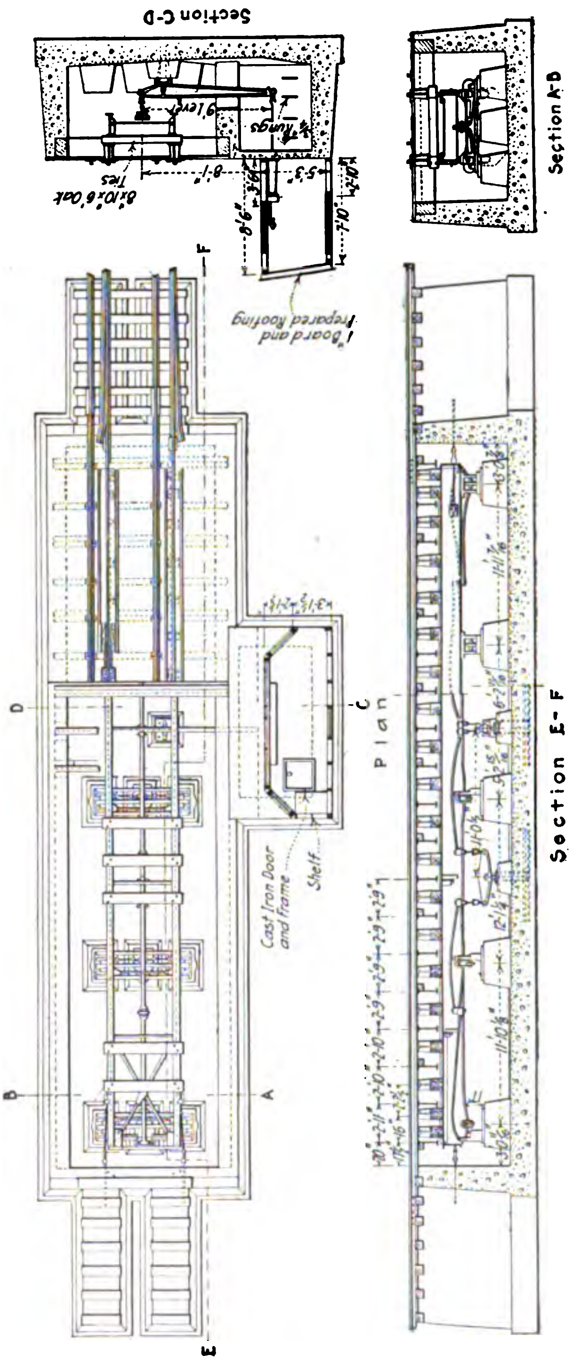


Fig. 136.—Track-scale.

the scale; deflection of weight-bridge; deflection of levers; binding of the scale platform; binding of the ends of scale- and track-rails; broken parts; dull bearings; levers out of line; and foreign matter in contact with the parts of the scale. Much of this trouble can often be traced to poor foundations.

194. Engine-houses.—Engine-houses may be either circular or rectangular. The circular form is built around a turntable from which radiate the tracks entering the engine-house. Each track within the engine-house provides a stall for housing one locomotive. The width of engine-house or depth of stall seldom is less than 80 ft. and depends on the length of the longest locomotive to be housed, allowing at least 7½ ft. at each end of the locomotive for passageways, swinging doors, etc. Rectangular engine-houses may have transverse stalls which are served by a transfer-table or a ladder track, or one or more tracks may run length-

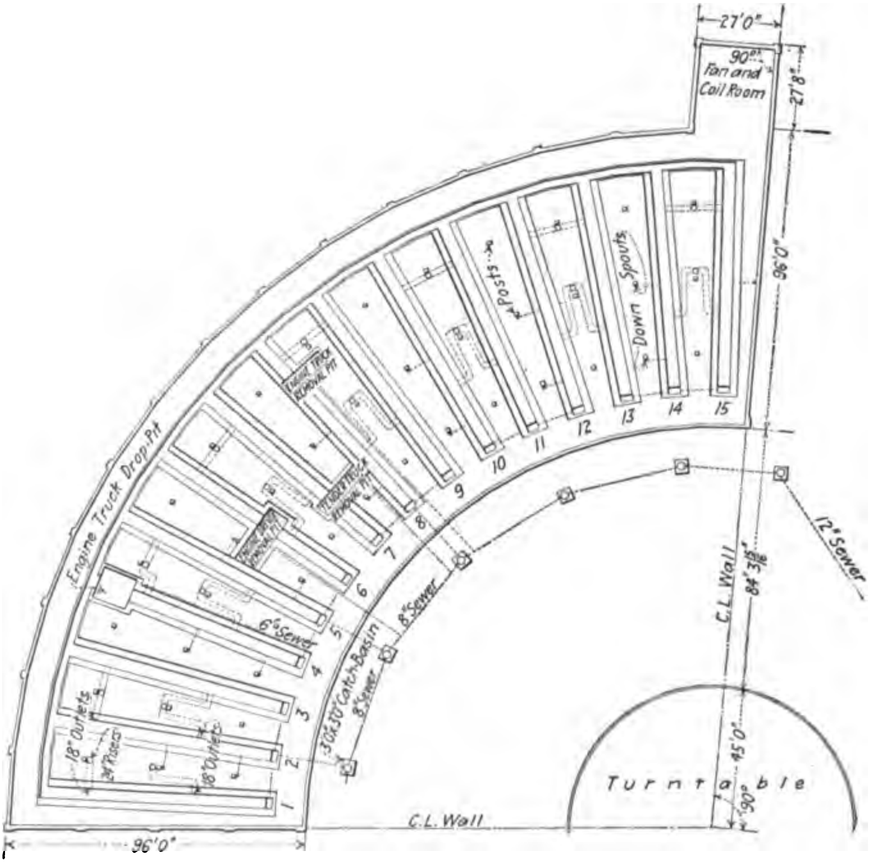
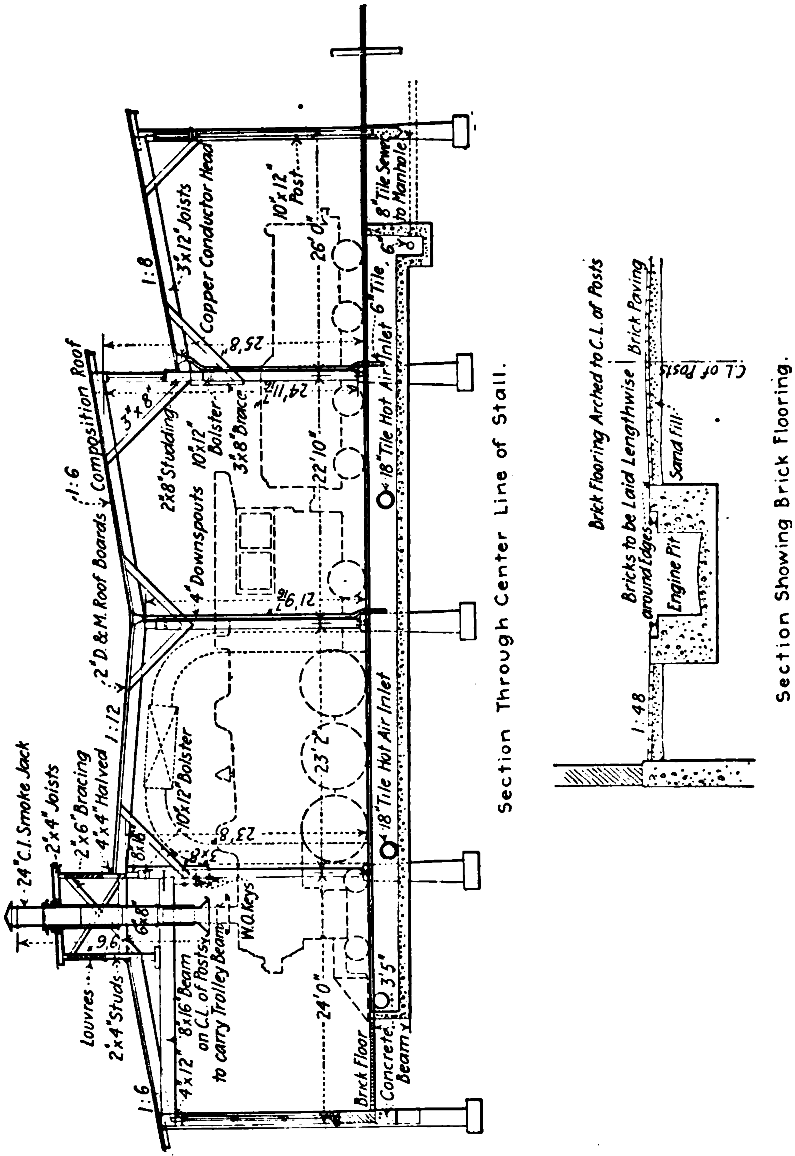


FIG. 137(*A*).—Circular engine-house, plan.

wise of the engine-house and several engines be housed on each track. The circular engine-house is economical at all places except as follows: (*a*) where not more than three or four engines are housed at a time; (*b*) where it is unnecessary to turn the engines; and (*c*) at shops where a transfer-table is used. Under these exceptions a rectangular house may be used economically. Every engine entering and leaving a circular engine-



Section Through Center Line of Stall.

Section Showing Brick Flooring.

FIG. 137(*B*).—Circular engine-house, section.

house must pass over the turntable. Hence the turntable is the throat of the house and when the turntable is out of order all engines in the house are tied up. The same is true of a rectangular house served by a transfer-table.

Engine-houses are used for cleaning and making light repairs to locomotives and for washing out the boilers. The engine-house capacity of a terminal is from 25 to 50 per cent. of the locomotives in service through the terminal. All parts of the building subject to corrosion from the gases should be protected. Engine-pits are constructed under the tracks for convenience in repairing and cleaning the under part of locomotives. The pits are from 50 to 60 ft. long and from 2½ to 3 ft. deep. Drop-pits for taking out wheels should be provided under several tracks. The locomotives in a circular engine-house stand with the tenders toward the turntable. A smoke-jack, used to conduct the smoke out of the house, is placed at the outer end of each stall over the stack of the locomotive. Thorough ventilation is an important factor. The building must also be equipped with a heating system and must be well lighted. Engine-houses usually are piped for water—often both hot and cold—compressed air, and steam. Boilers can be washed out quicker if hot water is used. The water for washing out boilers should be furnished under a pressure of 80 or 90 lb. Water-hydrants should be placed in alternate spaces between stalls. Compressed air and steam are used for blowing operations. The compressed air should be under a pressure of 80 to 100 lb. and the steam under a pressure of about 110 lb. Small machine-shops for making light repairs often are included in the engine-house.

The cost of a forty-two-stall engine-house of the Wabash Railroad at Decatur, Ill., was $84,500 complete without turntable. Brick engine-houses 75 ft. in width, of the Boston and Maine Railroad, have cost complete about $1600 per stall. The plan and section of a 15-stall, 96-ft. circular engine-house of the Chicago, Milwaukee and St. Paul Railway, at Aberdeen, S. D., are shown in Figs. 137(*A*) and 137(*B*).

195. Turntables and Wye Tracks.—In 1895 the average length of turntables was about 65 ft. In 20 years the length increased to about 85 ft. As the length increased the strength increased correspondingly; but at present both length and strength have fallen behind the increase in size of the largest locomotives now in service. Assuming the strength of the table to be sufficient to carry the loads with more or less safety, length is the most important feature of design. The length is determined by the length of wheel base and the position of the center of gravity of the longest locomotive to be turned. The table is turned easier if the loads on the two arms are balanced. The most unfavorable condition is an empty tender and a full boiler. If possible the length of the table should be such as to balance the engine even under these conditions. This requires a minimum length equal to twice the distance from the center of gravity to the rear tender wheel. If the engine is not balanced on the table the power required to turn it is considerable and the table and its supports are subjected to severe stresses for which they were not designed. A 90-ft. table will balance most of the heavy freight- and passenger-engines now in service, while a 100-ft. table will balance the medium-sized Mallet. The present standard length of turntables of American and Canadian railways is from 75 to 100 ft. Many shorter tables will be found on old lines and a few longer tables have been built for turning large Mallet engines.

Three types of turntables are used: (*a*) through, (*b*) half through or through girder, and (*c*) deck. Only a few through tables are being used and the through girder table is usually spoken of as a through table. Economy in pit-construction results from the use of a through table, but a heavier table is required. The track usually is of the open-floor type, but steel-plate floors have been used in a few cases. Hand-power is economical for operating the table if only a few light engines must be turned. Electric power is the most efficient.

Perhaps the most important part of the table is the center. Centers may be classified as conical roller bearings, disc bearings, and ball bearings; the numbers used are in the order given. Roller centers turn easier than disc centers.[1]

The hammering of the ends of a turntable from the wheels of entering engines is the most damaging feature in its operation. The shore rails are subjected to much the same shocks from leaving wheels, hence the circular rail which carries the wheels at the ends of the table, and the ends of the shore rails must rest on solid supports, preferably masonry. The turntable-pit should be paved throughout and properly drained. The center line of all tracks leaving the pit must be radial from the center of the table. There are three arrangements of tracks from the turntable to the engine-house: (1) Rails of adjacent tracks are placed with outsides together, thus requiring no frogs but requiring a long turntable. (2) Planing the outside of each rail and placing adjacent rails of two tracks together to form a frog-point without wing-rails, which allows the use of a shorter table than in (1). (3) Allowing the rails of adjacent tracks to cross, necessitating one less frog than the number of radial tracks; this is a very expensive arrangement to maintain. Latches are usually provided for locking the table in position at any pair of shore-rails. When a latch is used one should be provided at each end of the table. The most satisfactory latch consists of a heavy sliding tongue fastened to the table and sliding in a cast-iron socket set in the pit-wall. The tend-

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[1] For loads and unit stresses of the parts of turntables see Vol. 16, Proceedings, Am. Ry. Eng. Assn., page 657, etc.

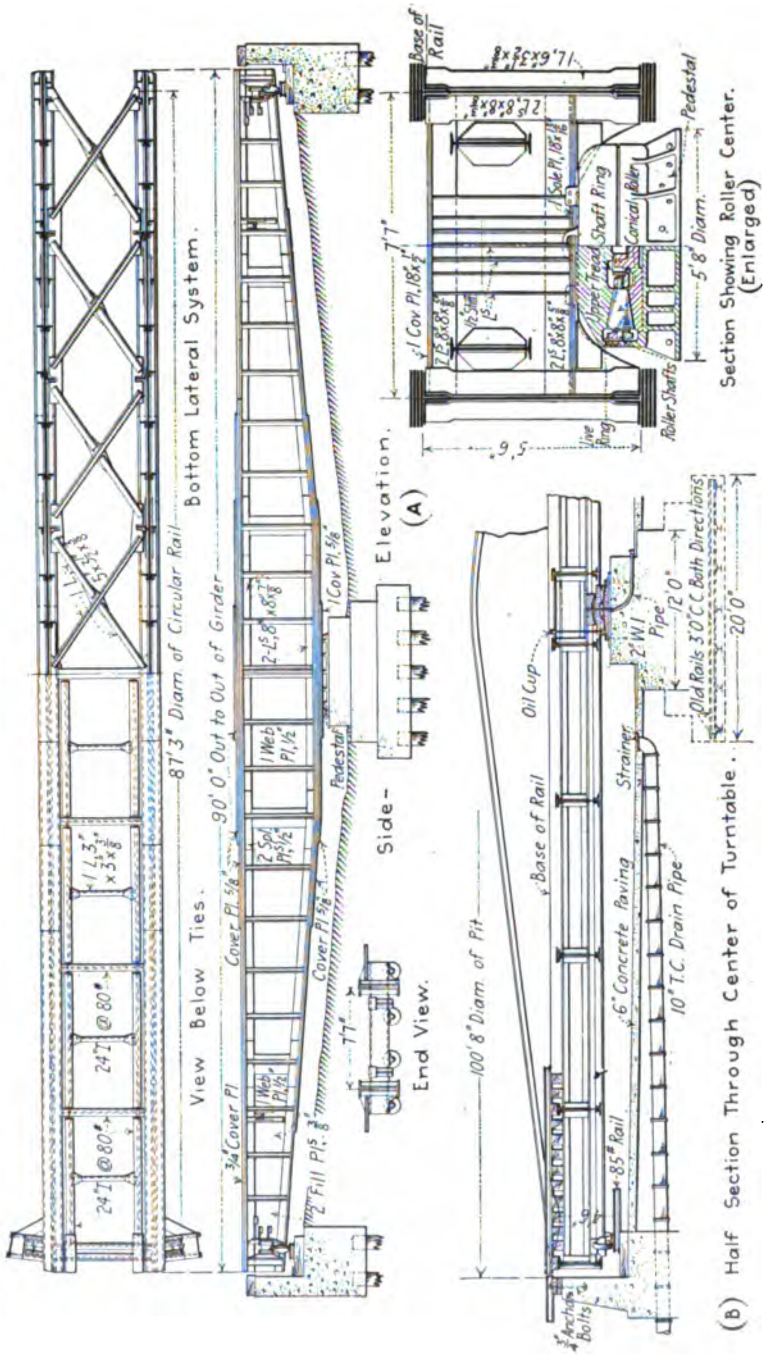


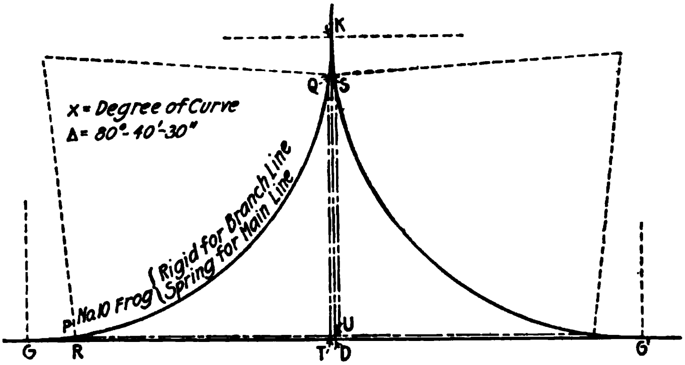
Fig. 138.—Turntables.

ency is toward the use of heavy power-operated tables without latches. The average cost of turntables is as follows:[1]

Deck tables, 75 ft.........	$7,500	Deck tables, 90 ft........	$9,500
Deck tables, 80 ft.........	8,000	Through tables, 85 ft......	11,500
Deck tables, 85 ft.........	8,750	Through tables, 100 ft.....	15,000

A 90-ft. half-through turntable of the conical roller-bearing type is shown at (*A*), Fig. 138, and a 100-ft. half-through disc-bearing type is shown at (*B*).

Where only a few long engines are in service wye tracks should be provided for turning these, all other engines using the turntables. Wye tracks are often used at the ends of branch lines, at junctions or at other points where it is necessary to turn several cars, as a passenger-train; and also at places where a small number of engines are to be turned. If the wye is not at a junction a stem track having a length sufficient to take the longest train to be turned must be provided. The data used on the Grand Trunk Pacific Railway for laying out a 90° wye by offsets are shown in Fig. 139.



X	GD	DK	GR	RP (=DU)	KS	SQ (=TD)	RD	SD	GG'
10°	611.7	615.0	94.1	4.7	75.2	2.35	517.6	539.8	1223.5
12°	526.1	526.1	94.1	4.7	75.2	2.35	432.0	450.8	1052.2
14°	465.0	462.6	94.1	4.7	75.2	2.35	370.9	387.4	930.0

FIG. 139.—Method of laying out wye tracks by offsets.

196. Maintenance-of-way Buildings.—The principal buildings under this heading are dwelling-houses for the section forces, section tool-houses, watchman's houses, storehouses for maintenance-of-way supplies, and movable dwellings for bridge-gangs and floating track-gangs. Section dwelling-houses are of three kinds: section-houses, in which both foreman and laborers live; section-foreman's houses and section-laborers' houses. The plans of these vary greatly on different railways. The general plans are based on climatic conditions and adaptability to different nationalities of laborers. If the section headquarters are situated at a place where accommodations in the neighboring community are not

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[1] 1912 Proceedings, Am. Ry. Bridge and Building Assn.

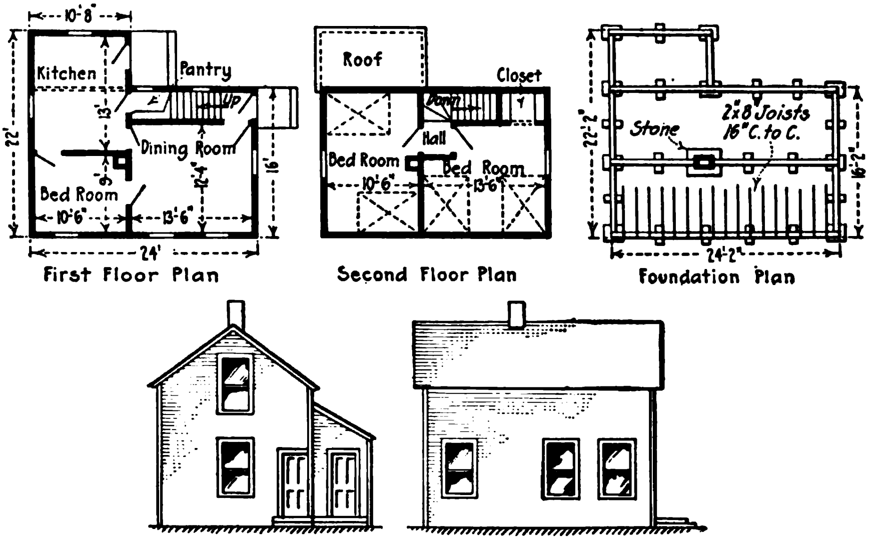
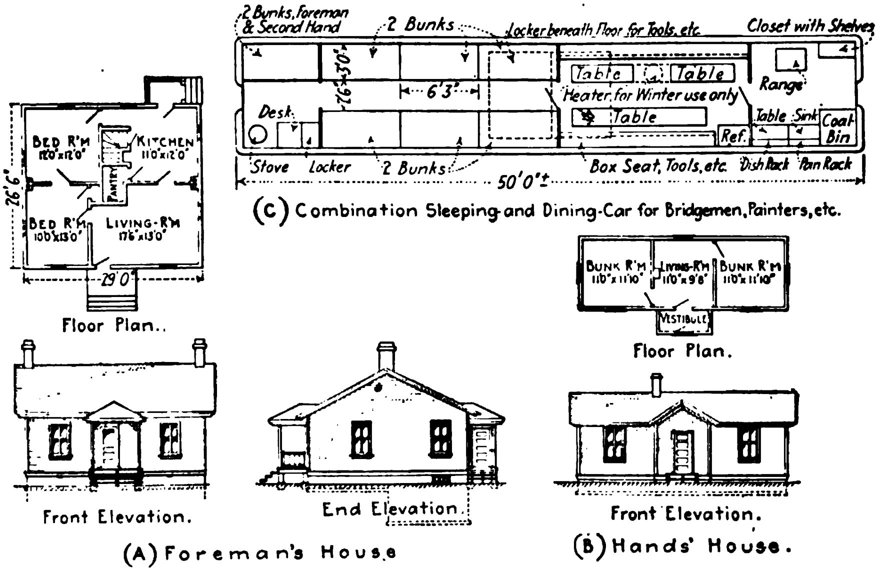


FIG. 140.—Section-house.



(C) Combination Sleeping- and Dining-Car for Bridgemen, Painters, etc.

(A) Foreman's House

(B) Hands' House.

FIG. 141.—Section-houses, and work-car for bridgemen.

available, a section-house must be provided. Under such circumstances the foreman's wife generally has charge of the house and boards the men of the gang. The house should be made comfortable and kept clean. The roadmaster must see that this is done. Section-houses are usually built of wood, but brick and concrete blocks are used on some railways. The Lehigh Valley Railroad recently has built several houses of concrete blocks. One of these, a 1½-story house containing an attic and three rooms on the second floor for use of the foreman and family, kitchen, dining-room and laborers' bunk-room on the first floor, and a basement, cost about $3750. A wooden house of the same size would cost from $1200 to $1500. This house will accommodate the foreman's family and from four to six laborers. A typical wooden section-house is shown in Fig. 140. The outside painting is Indian red with bottle green trimmings, and is sanded to a height of 6 ft. The inside is sealed. Figure 141 shows a section-foreman's house and a section-hands' house. Bridge-gangs are housed in old passenger-cars converted into living quarters. Floating gangs are housed in old box cars converted into bunk-cars. A combination sleeping- and dining-car which will accommodate a bridge-gang of fourteen men is shown at (*C*), Fig. 141.

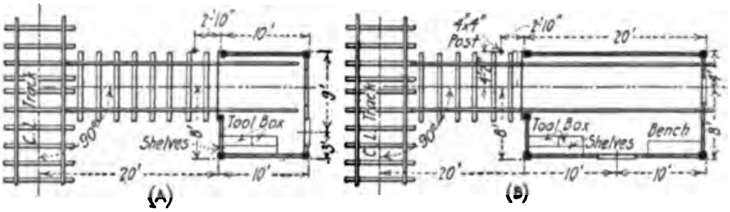


Fig. 142.—Section tool-houses.

A section tool-house is located at the headquarters of every section to provide a place for housing the section-car and section tools and supplies. The size of the usual tool-house is from 10 by 14 ft. to 14 by 20 ft. Small houses should be set with the narrow dimension perpendicular to the track. Large houses should be set with the long dimension perpendicular to the track. The two arrangements are shown in Fig. 142. The door should face the track and should have a clear opening of 8 ft. Double swinging doors are used where the size of house will not permit the use of a sliding door. The interior of the house should be provided with the necessary shelves, benches, bins, and racks so that there will be a special place for every tool and every class of material and supplies. It is the duty of the foreman to see that each piece is kept where it belongs. Much time is often wasted about untidy tool-houses hunting for misplaced paraphernalia. The details of a well-arranged tool-house are shown in Fig. 143. A tool-house track made of old rails or wood strips should be laid from the main track into the tool-house, as shown in Fig. 142. When the section-car is to be housed it is lifted clear of the main-

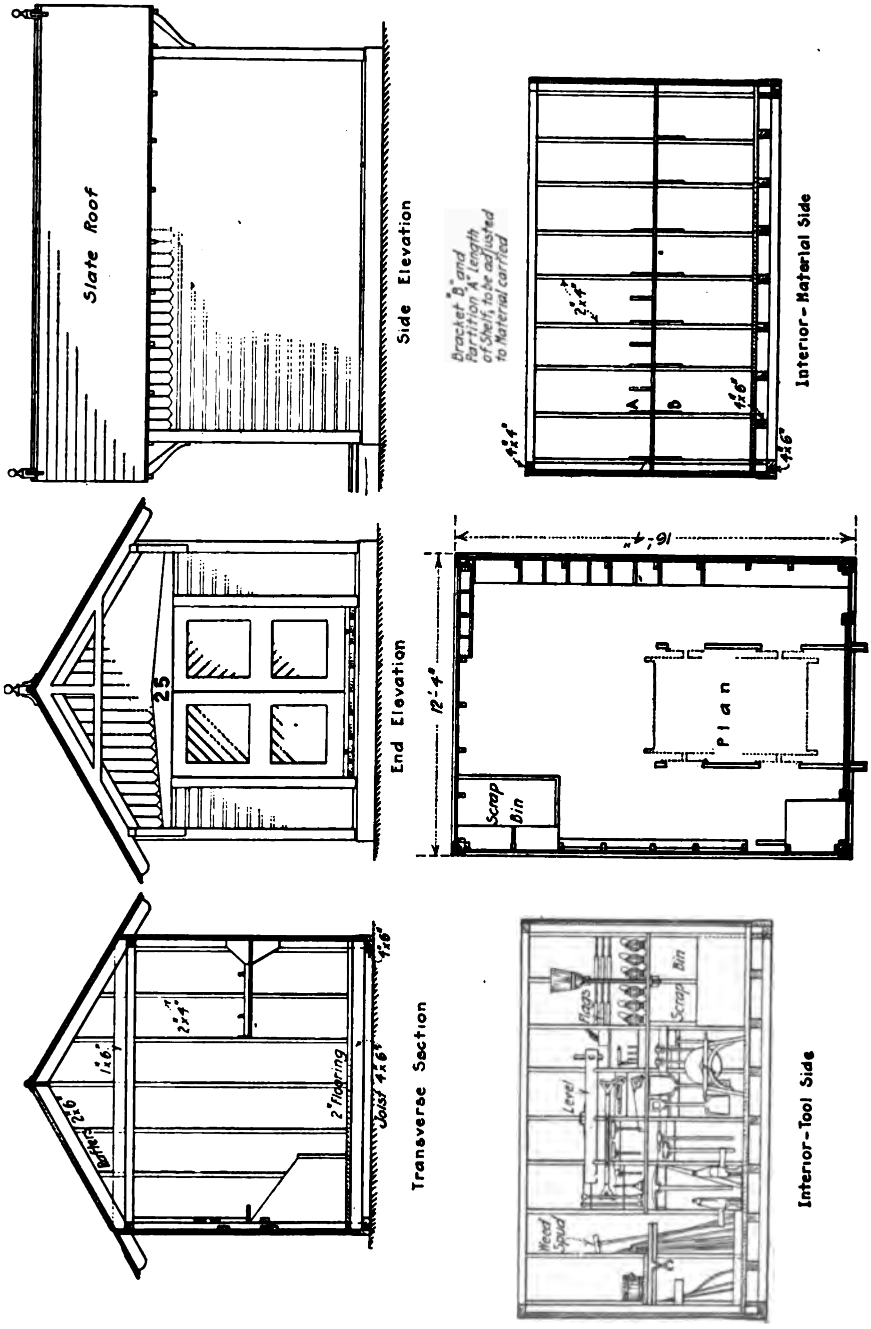


FIG. 143.—Details of a section tool-house.

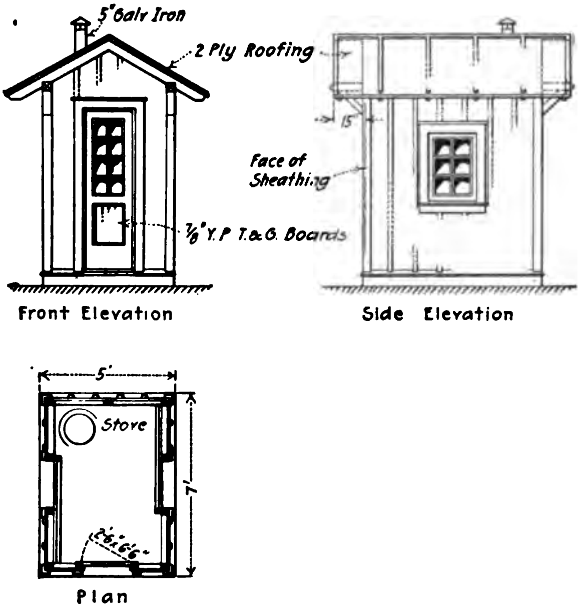


Fig. 144.—Watchman's house.

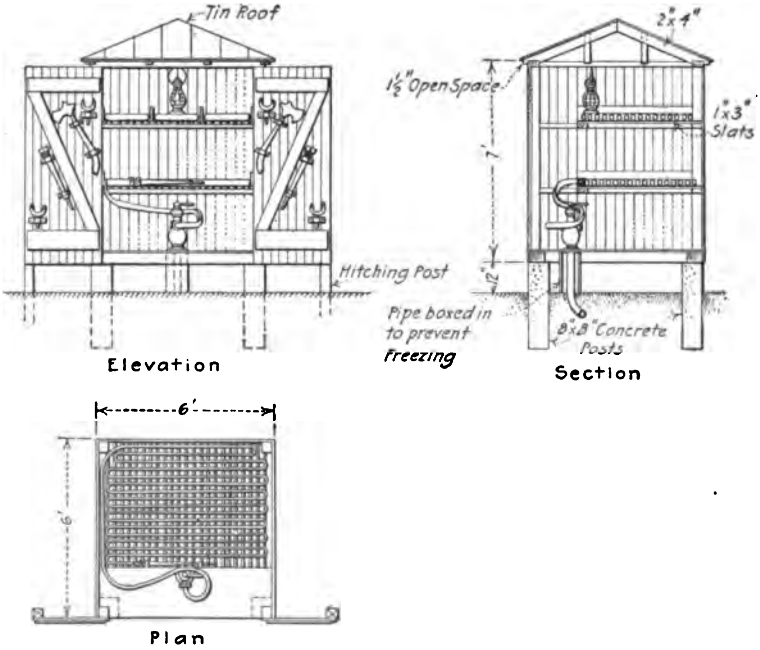
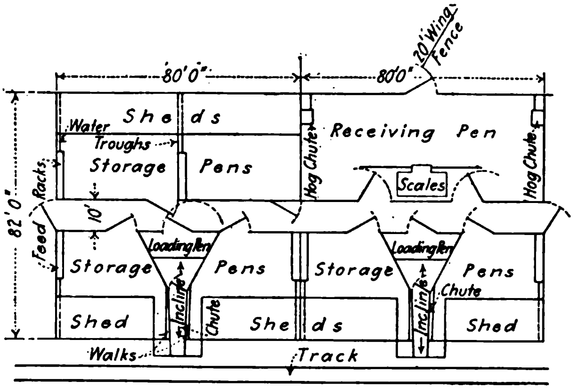


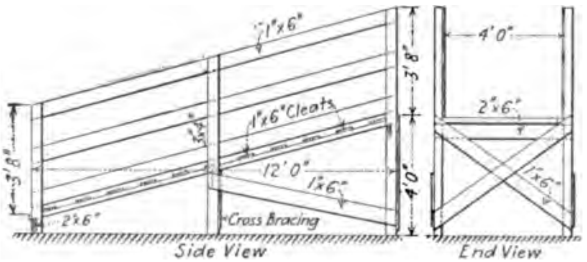
Fig. 145.—Fire-hose house.

track, turned 90° and placed on the tool-house track. In some cases a track is not provided and the car must be carried into the house. The floor of the house is often made of cinders. A scrap-bin should be built back of the tool-house for storing metal scrap until removed occasionally by the work-train. A floored and solid-walled bin about 6 ft. square and 2 ft. deep, constructed of second-hand ties or bridge timbers is sufficient.

At divisional points a storehouse is maintained, from which the section-foremen secure regular tools and supplies, frogs, switch-rails, special tools, etc.



(A) Plan of Stock-Yard.



(B) Stock-Chute.

FIG. 146.—Stock-yard.

Small houses or cabins are provided as shelters for crossing watchmen and gate tenders. The house is usually placed on the ground but where this would be unsightly or space is not available the house is mounted on a column and is called an aërial watch box, or watch tower. A common form of watchman's house is shown in Fig. 144. Where several railway-buildings are grouped, a fire-hose house is often built. This contains axes, wrenches, etc., and a hydrant to which the hose is already attached. A fire-hose house built by the Baltimore and Ohio Railroad is shown in Fig. 145.

197. Stock-yards.—At all points where the railway receives, delivers, or rests stock, stock-yards must be provided. A stock-yard consists of one or more fenced enclosures and an incline, called a stock-chute, leading to a platform beside the track and at about the same elevation as the floor of the stock-cars. If several kinds of stock are to be handled the yard should have one or more compartments for each. Even if but one kind of stock is handled several small compartments are better than one large inclosure. Board or plank fences are commonly used and if the stock is held for any length of time shelter sheds should be provided. Also means for feeding and watering the stock must be provided. The minimum space required for stock standing over 6 hr. should be about 5 sq. ft. for sheep, 10 sq. ft. for hogs, and 30 to 40 sq. ft. for cattle. This does not apply to space occupied in cars while in transit.

The fence should be of strong construction and should be not less than 5 ft. high. If many head of cattle are to be handled a platform-scale should be installed. The form of stock-yard used on the Missouri Pacific Railway is shown in plan at (*A*), Fig. 146, and the detail of a stock-chute is shown at (*B*).

198. Station-platforms.—The elevation of the outer edge of station-platforms above the top of rail is about 6 in. for passenger- and light freight-traffic. Where only a small amount of freight is handled, freight-platforms level with the car-floor are unnecessary. Where a large quantity of freight is handled the height of platform should be approximately that of the car-floor. This varies somewhat on different railways. Where refrigerator cars are not handled in large numbers the platform should be approximately 4 ft. above the top of rail. If refrigerator cars are handled regularly the platform should be not more than 3 ft. 8 in. above the rail to allow for opening the car-doors. High freight-platforms should not extend nearer the main track than the front of the station-building, where the station is a combined freight- and passenger-station. Platforms used exclusively for freight should be from 8 to 10 ft. wide. If motor-trucks are used the width should be not less than 12 ft. On tangents the face of a freight-platform or freight-house should be 5 ft. 9 in. from the center of the nearest track. If inflammable materials such as cotton, oil, etc., are to be handled, the loading platform should be isolated from other buildings. If the freight- and passenger-station are combined at small cities, and a large amount of freight is handled, the elevated platform may be placed at the rear of the station and be served by a track back of the station. This should be avoided where possible, as it requires at least two main-line switches; but it is necessary if unloading from the main track will delay other trains.

Station-platforms are constructed of cinders, stone screenings, wood, brick, and concrete. Platforms of material other than wood and concrete require a curb adjacent to the track. Cinders and stone screenings are used for suburban passenger-platforms. Wood is used for both passenger-

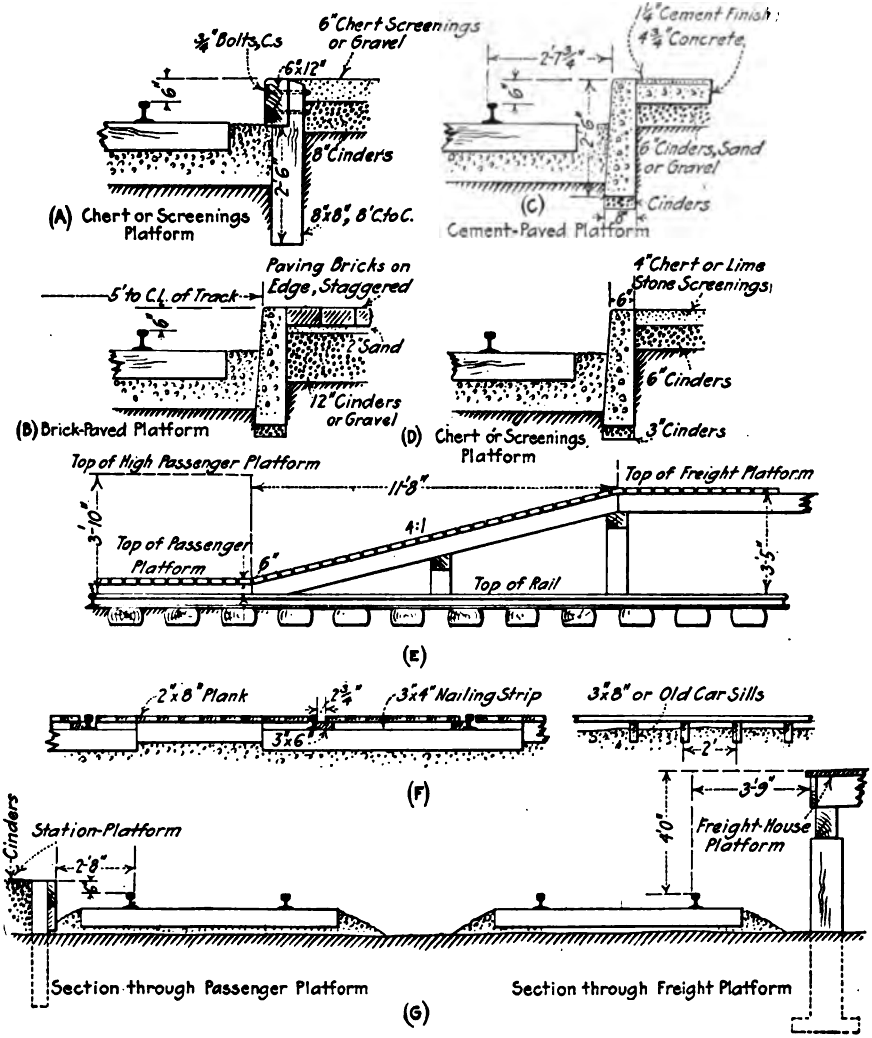

¾" Bolts, C.S
6" Chert Screenings or Gravel
6"x12"
6"
8" Cinders
2'-6"
(A) Chert or Screenings Platform
8"x8", 8' C. to C.
1¼" Cement Finish; 4¾" Concrete
2'-7¾"
6"
6" Cinders, Sand or Gravel
Cinders
8"
(C) Cement-Paved Platform
Paving Bricks on Edge, Staggered
5' to C.L. of Track
6"
2" Sand
12" Cinders or Gravel
(B) Brick-Paved Platform
4" Chert or Lime Stone Screenings
6"
6" Cinders
3" Cinders
(D) Chert or Screenings Platform
Top of High Passenger Platform
11'-8"
Top of Freight Platform
3'-10"
Top of Passenger Platform
6"
4:1
Top of Rail
3'-5"
(E)
2"x8" Plank
2¼"
3"x4" Nailing Strip
3"x6"
3"x8" or Old Car Sills
2'
(F)
Cinders
Station-Platform
2'-8"
6"
4'-0"
3'-9"
Freight-House Platform
Section through Passenger Platform
Section through Freight Platform
(G)

FIG. 147.—Station-platforms.

and freight-platforms in small towns and for freight-platforms in cities. Concrete and brick should be used for all passenger-platforms in cities and are also economical for freight-platforms in cities. When wet, a concrete pavement is slippery, and when cracked or damaged by frost, falling packages, etc., it is difficult to repair. A brick platform is likely to become uneven and when in such condition is inconvenient to walk over and is hard to truck over. Cement platforms are usually about 6 in. thick and are laid on a cinder base at least 6 in. thick. Such a platform costs from 12 to 18 cts. per square foot. Brick used for platforms should be well vitrified, laid on a gravel, cinder, or concrete base, and the joints should be sanded or grouted. Inter-track platforms may be made of cinders, screenings or plank and should be level with the top of rail. Different arrangements of platforms and types of construction are shown in Fig. 147.

199. Station-buildings.—The size and design of a station-building is determined by the character and volume of business handled. In small towns the passenger, freight, and express business are handled at one building. In cities the passenger and express business often are handled at one building, which may also include offices for various divisional or district officials. In some cases the freight house and passenger-station are in separate buildings served by the same platform and tracks. At suburban passenger-stations an open-front shelter-house, such as that shown in Fig. 148, is all that is necessary. A passenger-terminal for a divisional point is shown in Fig. 149.

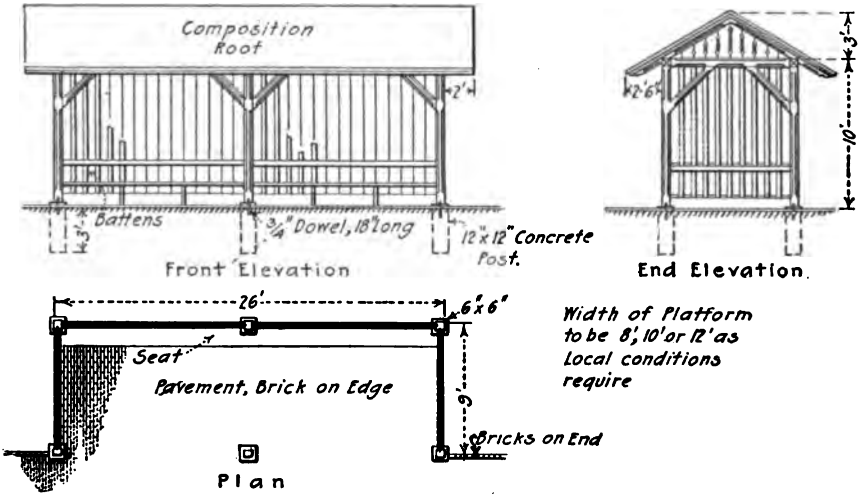
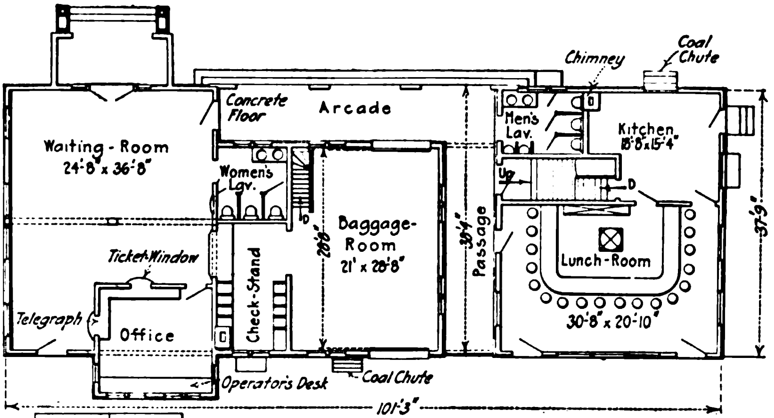
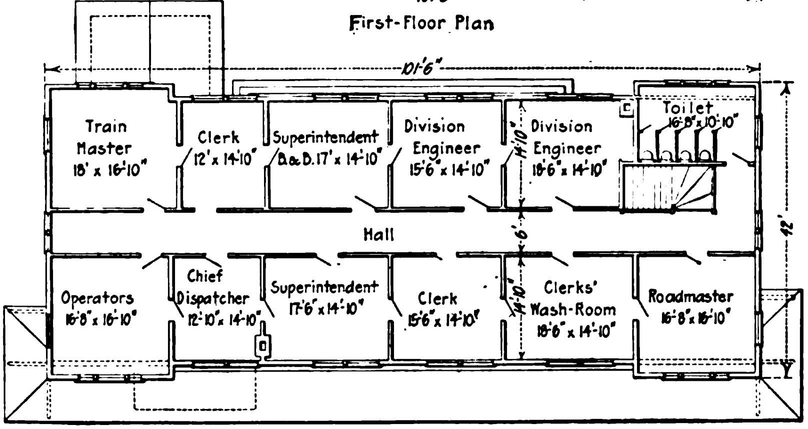


FIG. 148.—Shelter-house.

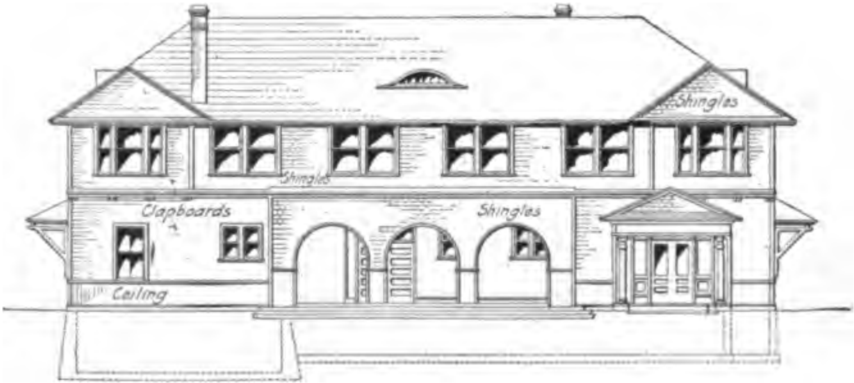
The essential parts of a passenger-station are a general waiting-room, women's rest-room, lavatories, ticket- and telegraph-office, and baggage-room. For all but stations in large cities these are housed in a rectangular building from 20 to 45 ft. wide and from 50 to 125 ft. long, which has a bay window in the telegraph-office. The most economical arrangement, when a separate waiting-room for colored people is unnecessary, is a general waiting-room in the middle of the building, with the baggage-room



First-Floor Plan


101'6"
Train Master 18' x 16'10"
Clerk 12' x 14'10"
Superintendent B.& B. 17' x 14'10"
Division Engineer 15'6" x 14'10"
Division Engineer 18'6" x 14'10"
Toilet 16'8" x 10'10"
14'10"
Hall
6'
42'
Operators 16'8" x 16'10"
Chief Dispatcher 12'10" x 14'10"
Superintendent 17'6" x 14'10"
Clerk 15'6" x 14'10"
14'10"
Clerks' Wash-Room 18'6" x 14'10"
Roadmaster 16'8" x 16'10"

Second-Floor Plan



Approach Elevation

FIG. 149.—Passenger-terminal for a divisional point.

and ticket-office at one end, and the women's rest-room and lavatories at the other end. This arrangement offers economy in heating, admits of a smaller building without sacrificing facilities, permits ease of access from the agent's office to trains and all parts of the building, and permits proper proportioning of the various rooms. The American Railway Engineering Association recommends the following division of floor space for an arrangement of this kind: general waiting-room 41 per cent., women's rest-room 10 per cent., lavatories 8 per cent., ticket- and telegraph-office 15 per cent., and baggage-room 26 per cent.

The materials used in the construction of station-buildings are wood, brick, masonry, concrete and steel, or a combination of two or more of these. The most important materials used for roofing are (1) felts made of rags, jute, or asbestos and used with bituminous substances and often covered with gravel to act as a fireproofing, (2) slate, (3) clay or cement tile, and (4) metal. When laid on a flat roof the individual pieces of material must be cemented together, as in the ordinary tin roof. On a steep roof the pieces or strips are laid to overlap with broken joints, shingle fashion.

The floors of freight houses are of two general types: (1) resting on a solid fill, or (2) joist construction. The filled floor will carry any loads liable to come upon it, costs less to maintain, and reduces the fire hazard. Joist floors should be designed to carry a load of 250 lb. per square foot. The width of a combined inbound and outbound freight house should be from 30 to 40 ft. The width of a separate outbound freight house should be not greater than 30 ft. As a greater storage capacity is required for an inbound freight house the width should be from 40 to 60 ft. A platform should be provided on the track side of the house to avoid the necessity of spotting the cars at doors. This may be undesirable in climates where much snow collects on the platform. The platform should be protected by an overhang of the roof of the building equal to the width of the platform.

200. Snow-sheds.—A railway should be so located that snow-sheds are necessary only as a protection from mountain snow-slides. In the mountains of the West snow-sheds are necessary in many cases where a track on the side of a mountain is all in cut or in side-hill cut. On the western slopes of the Cascade and Sierra Nevada Mountains this trouble is unusually severe. A snow-shed is a comparatively tight shed built over the track to provide an unbroken path for the passage of avalanches of snow. The usual snow-shed is of timber construction. A combination of timber shed and concrete retaining wall on the up-hill side of the track, has also been used. The sheds must be so located that the direct thrust of the snow will not come upon the up-hill side of the shed. The construction throughout must be very substantial and the structure must be rigidly braced laterally, both inside and on the down-hill side.

During the summer of 1913 the Great Northern Railway constructed about 14,600 lin. ft. of snow-sheds in a distance of 9 miles, which already had 14,000 ft. of sheds. The roof consisted of 12- by 12-in. timbers resting on columns 12 by 12 in. or larger. Where slides would not lodge on the roof, the sheds were designed for a load of 500 lb. per square foot. Where heavy slides were possible or where the slides might lodge on the roof, the sheds were designed for a load of 900 lb. per square foot.

201. Bumping-posts and Car-stops.—Bumping-posts or car-buffers are placed at the ends of stub tracks to stop cars which, through error in judgment of trainmen or defective brakes, would run off the end of the track. The object of the device is to effectually stop cars which strike it, and to do so in such a manner as to do the least injury to car and contents and adjacent property. The heavy, high-capacity passenger- and freight-cars of the present require the use of very strong bumping-posts. Broadly speaking, bumpers are of two kinds: (*a*) those which themselves absorb most of the shock, and (*b*) those in which most of the shock is absorbed by the train. The first class includes hydraulic bumpers,

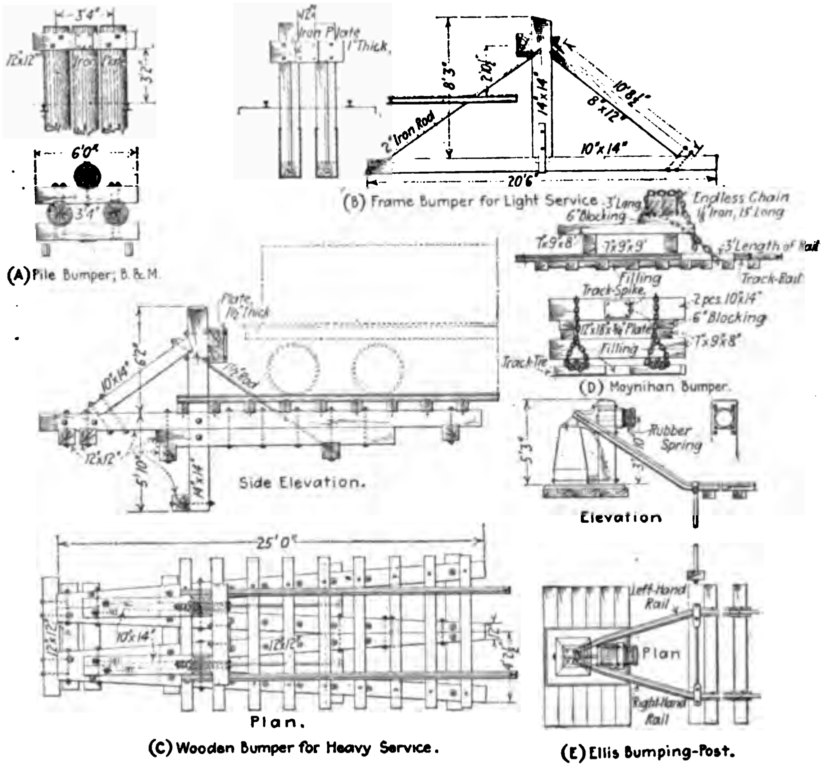
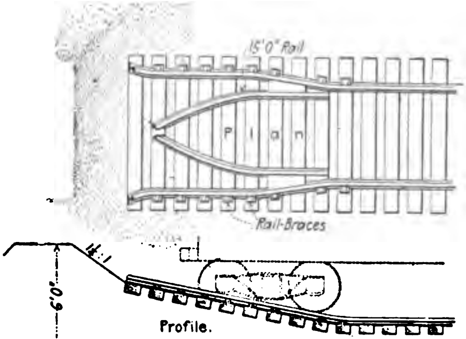
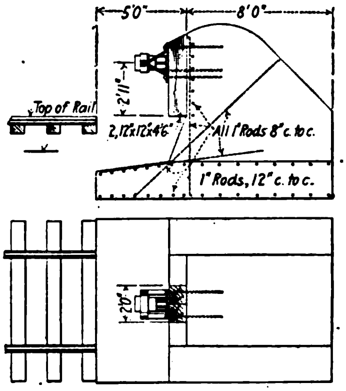

(A) Pile Bumper; B. & M.
(B) Frame Bumper for Light Service.
(C) Wooden Bumper for Heavy Service.
(D) Moynihan Bumper.
(E) Ellis Bumping-Post.

FIG. 150, Part 1.—Bumping-posts and car-stops.

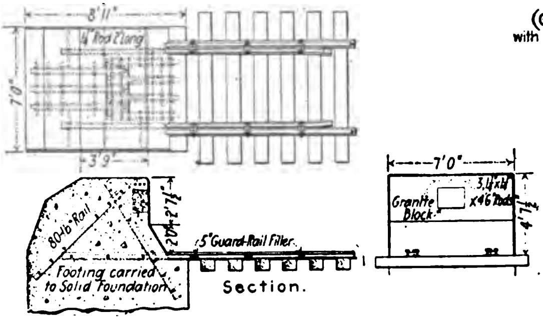
used on European railways, spring bumpers, sand tracks, and a pile of dirt or sand at the end of the track. To the second class belong the great variety of rigid bumpers in use on American railways. The hydraulic bumper consists of a frame carrying a hydraulic cylinder with a long-stroke piston. This acts as a dash-pot when a car strikes it. The old-fashioned pile of dirt is one of the most effective car-stops but is unsightly and requires considerable space. Rigid bumpers are constructed of wood, metal, or concrete. In some types a shoe resting on the rail engages the wheel, or the ends of the rails may be bent up to do the same thing. In most cases the bumper is anchored to the track in front and is braced from the rear. A bumper consisting of a cluster of piles bolted together has given good service on several railways. An earth buffer should be not less than 3 ft. high, about 12 by 12 ft. square and the slopes should be not steeper than 1½ to 1. Several types of bumpers are shown in Fig. 150. The Ellis bumping-post, shown at (*E*), is a patented device and makes use of a rubber spring. As the deterioration of rubber is rapid, coiled steel springs are much more serviceable as a shock absorber.

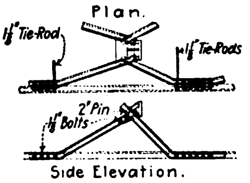


(F) Earth Car-Stop for Freight-Tracks.



(G) Reinforced Concrete Bumper with Westinghouse Friction Draft-Gear





(I) Buda All Steel Bumping-Post (for Freight Service, 60 to 100-Lb Rail.)

(H) Reinforced Concrete Bumper, D.L.&W.

FIG. 150, Part 2.—Bumping-posts and car-stops.

202. Telltales.—Telltales or "ticklers" are used to warn trainmen standing on a car-roof of the approach of a low overhead structure. They are unnecessary for structures 22 ft. or over above the top of rail. The usual form of telltale consists of a row of dangling ropes or small wire rods. For single track these are suspended from the arm of a pole set beside the track. For two or more tracks they are suspended from a cable or rod swung between poles on each side of the track. The arm or cable is placed above the maximum overhead clearance limit. The length of the pendants depends on the height of the structure above the top of rail. The pendants should extend at least 3 in. below the lowest clearance line of the structure and 4 ft. on each side of the center line of the track. A few railways make the telltale 10 ft. wide and a few use a width of only 6 ft. The spacing of the pendants is from 3 to 6 in., about 4 in. being the most reliable spacing. All tracks, whether one or more, should be protected in each direction. The telltale should be placed from 100 to 300 ft. from the structure on main tracks and from 50 to 100 ft. on yard-tracks and switching tracks. If structures are close together a telltale should be placed between them.

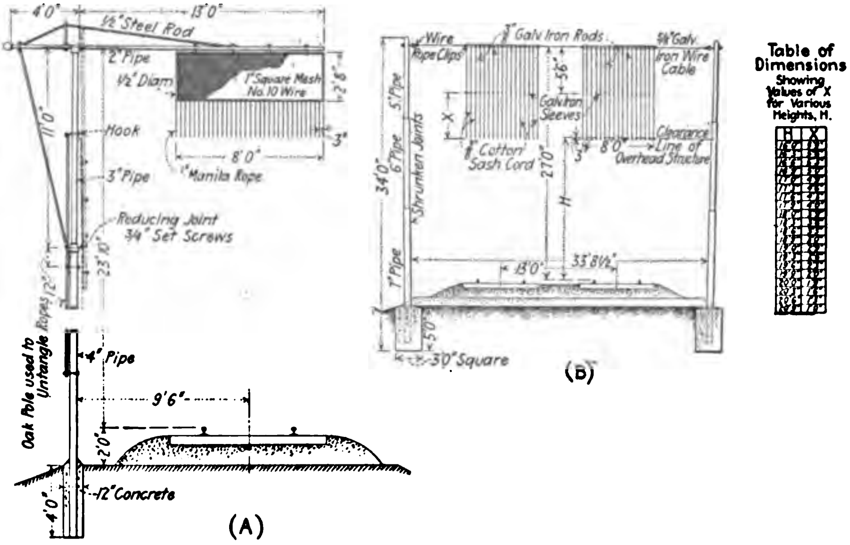


Fig. 151.—Telltales.

The New York Central Lines use English gage spring-brass rods hung from 2-in. eyelet screws in a wooden arm or piece attached to a cable. The Baltimore and Ohio, Erie, Northern Pacific, Frisco, etc., use a suspended wire screen for the upper part and hang cords from this. The screen of the Baltimore and Ohio and Erie is 2 ft. 6 in. wide and is made of No. 10 wire with 1-in. square meshes. A common practice is to use

¼- or ⅜-in. wire rods for the upper part of the pendant and ⅜- or ½-in. rope for the lower part. Ropes are less liable to injure a person than rods but have a tendency to get tangled and when this occurs must be untangled by the trackmen. Two types of telltales are shown in Fig. 151.

A few railways have tried the use of side telltales to warn switchmen hanging to the sides of cars of the approach of a narrow opening. These consist of pieces of rubber hose projecting horizontally toward the track, or a frame revolving about a vertical axis, and having projecting arms of some flexible material. A telltale consisting of a low fender has been used at pit stock-guards as a warning to track-walkers.

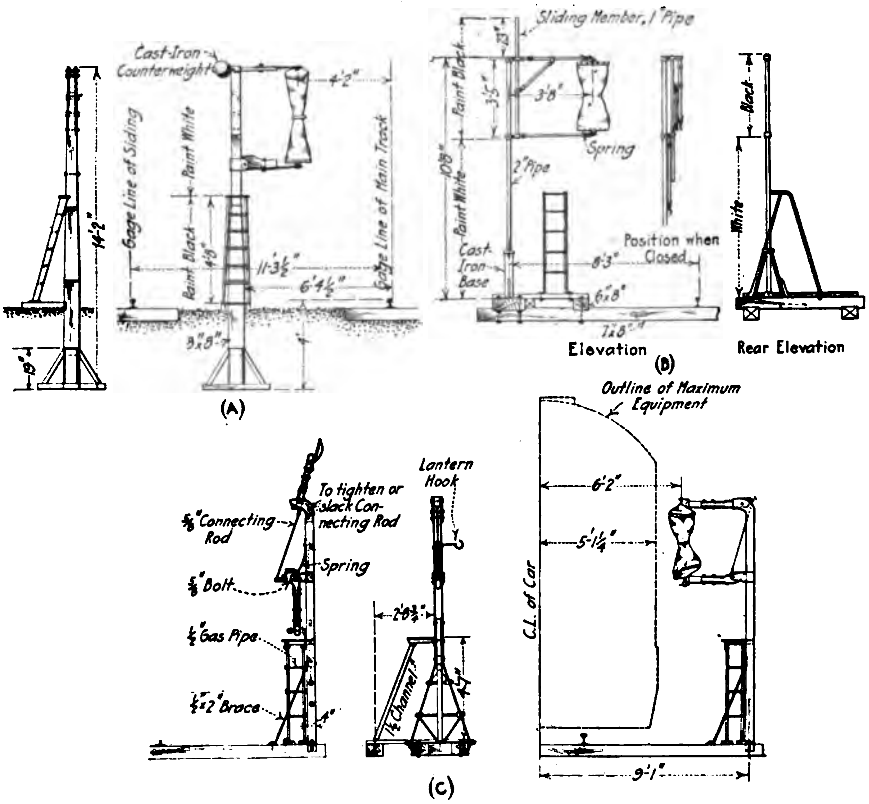


FIG. 152.—Mail-cranes.

203. Mail-cranes.—A mail-crane is a metal or wooden frame placed by the side of the track at stations where mail-carrying trains do not stop. It is used to hold the mail-bag in position to be caught by the mail-catcher on the moving train. The crane consists of a post to which are attached two arms perpendicular to the track. The arms are hinged to move in a vertical direction, the bottom arm downward and the top arm either upward or downward. When not in use the arms swing to a vertical position by gravity. The mail-bag is given a twist of 180° or a ring is placed around the middle and the bag is then suspended between the arms. The height of the post and the position of the arms must be such that the center of the mail-bag is approximately at the same elevation as the mail-catcher, and the distance from the center of the track is fixed by the size of car and reach of mail-catcher. Where there are more than two tracks it may be necessary to place the crane between tracks. It is then necessary to increase the distance between track centers to 15½ or 16 ft. If the crane is located on the ground a low ladder must be provided for use of the person who places the mail-bag. The upper arm of the wooden crane of the Pennsylvania Railroad, shown at (*A*), Fig. 152, swings upward by the action of a counterweight back of the post. Both arms of the metal crane shown at (*B*) swing downward. When the mail-bag is in position a vertical sliding member, attached to the upper arm, rests on the lower arm. When the mail-bag is collected, the sliding member pushes down on the lower arm and pulls down on the upper arm; hence each part tends to aid the other parts in collapsing. The arms of the crane shown at (*C*), which is used on the Boston and Albany, the Grand Trunk Pacific, etc., move in opposite directions. Cranks back of the pivots of the two arms are connected by a rod and the movement of the lower arm is controlled by a spring.

204. Miscellaneous Accessories.—A mail-receiver is a platform adjacent to the track for receiving mail-bags thrown from moving trains. In most cases mail-receivers are not used, the mail-bags being thrown from the car at the station and allowed to alight where they may. Where used, a mail-receiver should be about level with the top of ties at its outer edge and should slant slightly away from the track; a low railing, about 12 in. high, should be on the track side and the other sides should have solid fences about 3 ft. high. The platform should be at least 30 ft. long and 8 or 9 ft. wide.

Section-car rests are earth platforms provided at the side of the track as a resting place for the section-car when the section-gang is working near by. They should be covered with at least 3 in. of ballast; should be about 14 ft. square, or large enough to hold the car; level with the top of tie; located where the ground surface is about level with the roadbed; and about ½ mile apart. Rails perpendicular to the track may be provided for holding the car, but this is unnecessary.

When it is necessary to locate a sign-post a certain distance from the track which would place the post a few feet beyond the edge of the roadbed on a fill, the roadbed should be widened at that place to form a level platform at about the same elevation as the roadbed, and of such size as to allow 2 or 3 ft. between the post and any edge of the platform. A platform of this kind is shown in the location plan in Fig. 153 (*B*). In a few cases also cuts are widened to form a similar platform for a sign-post.

For emergency purposes extra rails should be placed at intervals along the track. These are placed on rail-racks or rests which consist of two or three posts with arms, notches, or steps for holding from one to six rails. Three types of rail-racks are shown at (*A*), (*B*) and (*C*), Fig. 153. Rail-racks should be located at or near mile-posts. The Erie Railroad places a one-rail rack at each mile-post. The Wheeling and

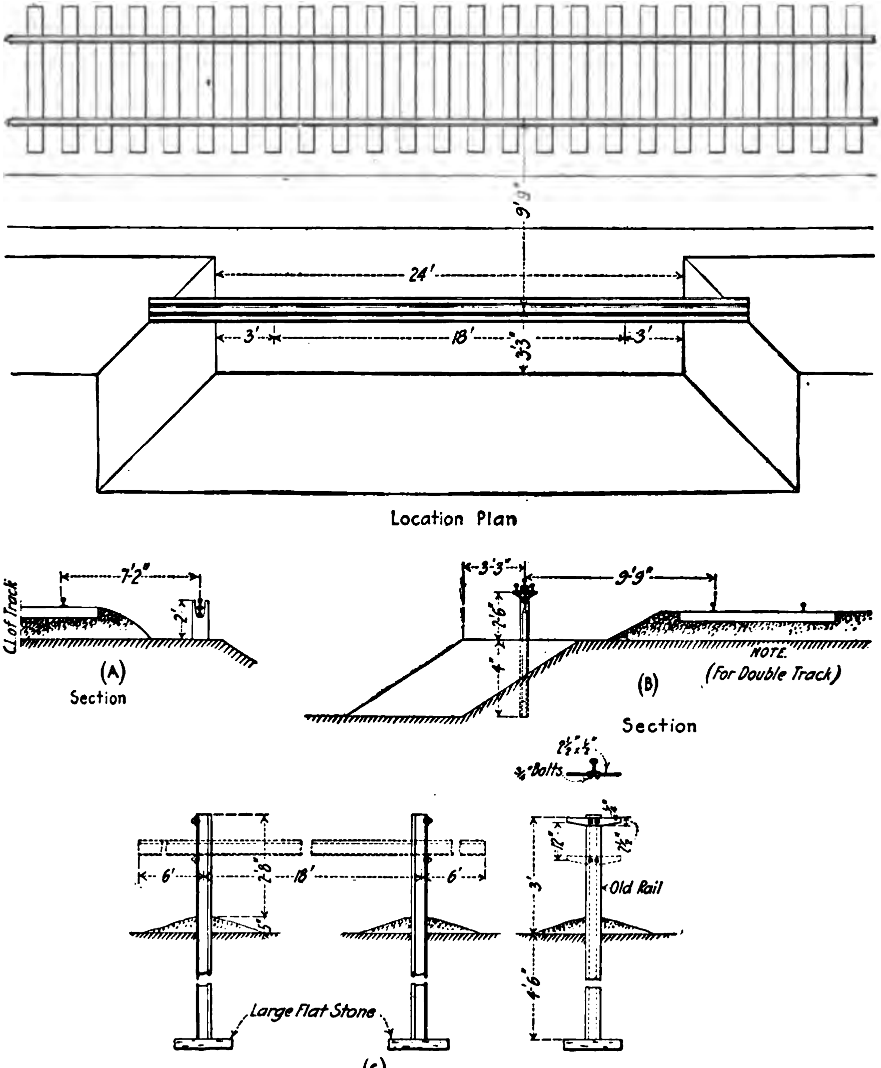


Fig. 153.—Rail-racks.

Lake Erie Railroad places the racks 2 miles apart where practicable and each rack carries two rails for single track, four rails for double track, and six rails for four tracks and tracks in yards. This rack is shown at (*C*).

Telegraph-poles should be placed 30 ft. from the center of the track or as near this distance as the width of right-of-way will permit. The ends of cross-arms should be not less than 1 ft. from the edge of the right-of-way. A few hundred feet of telegraph-wire should be kept in the section tool-house. In going over the section the foreman should note the general condition of the telegraph line. If wires are broken he must make temporary repairs, awaiting the arrival of the lineman. The position of the train-order wire should be known and this wire should be repaired first. The lowest cross-arm on the pole should be not less than 20 or 25 ft. above the ground at highway and railway crossings and through station-grounds, and 15 to 20 ft. elsewhere. The poles are spaced from 150 to 176 ft. apart, or from 35 to 30 per mile. The number of cross-arms depends on the number of wires to be carried. The size of cross-arm is usually 3¼ by 4 or 4½ in. A 7-ft. cross-arm will carry six wires spaced 15 in. apart, while the spacing on an 8-ft. arm is 17½ in. Several methods are used for fastening the cross-arm to the pole. Two common methods are to dap the arm about 1½ in. into the pole and use two bolts staggered, or to use one bolt and two 45° ¼- by 1¼-in. iron braces about 28 in. long, fastened to the arm with one or two bolts and to the pole with one bolt or lag-screw. The details of this arrangement are shown in Fig. 154. The length of poles is from 18 to 45 ft. A 25-ft. pole should be set 5 ft. in the ground and for each additional 5 ft. in length the pole should be set 6 in. deeper. The diameter of the top of poles 25 ft. or more in length should be not less than 8 in. The top

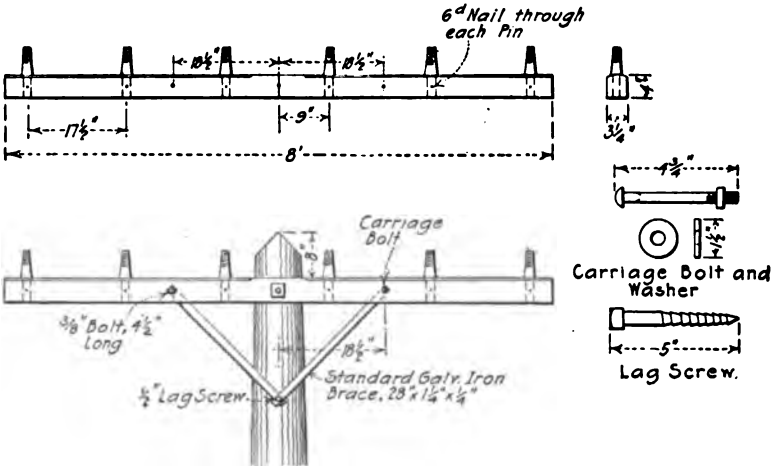


Fig. 154.—Cross-arm for telegraph-pole.

should be cut wedge-shaped. The wire usually is No. 8 American gage B. S. or its equivalent. At angles where the first pole beyond the angle is 10 ft. or more in a perpendicular offset from the center of the pole line extended, double cross-arms are usually used on the first pole on each side of the angle. Poles should be so located at angles that the small angle is not less than 150° or 160°. Corner-poles should have double arms for all but very small changes in direction. Corner-poles must be side-guyed, the foot of the guy being at least 8 ft. from the base of pole. The first pole on each side of the angle should be guyed toward the angle, the anchor being set about 20 ft. from the pole or at such a distance that the angle of the guy is at least 30° with the vertical. The anchor consists of an inclined post or rod set 5 or 6 ft. in the ground, and having one or two crosspieces on the lower end. In rock an inclined hole is drilled and a rod is set in concrete in the hole. Poles in depressions of the ground should be head-guyed to the next pole on the high side. On bridges across large bodies of water the cross-arms are either fastened to the floor system of the bridge and extend outside the trusses, or are carried above the trusses on short masts. For spans over 400 ft. long the spacing of wires should be increased to 2½ or 3 ft. Power transmission lines, cable, telephone, and telegraph wires crossing the right-of-way should be carried across underground where possible.

CHAPTER XV

BRIDGES, TRESTLES, AND CULVERTS

205. Classification of Bridges.—A discussion of the principles of design of steel bridges and a description and history of the development of the many types of bridges now in use is entirely without the scope of a book of this character. A bridge is any structure erected above the normal surface of the earth used exclusively for the passage of traffic of any kind. According to the position of connection of the floor system to the trusses and depth of trusses, bridges may be classified as through, half through or pony truss, and deck. The trusses of a through bridge are connected at the bottom by the floor system and at the top by the system of top lateral bracing. A half-through truss has no top lateral bracing. The trusses of a deck bridge are connected at the top by the floor system. On a basis of design or method of construction bridges may be classified as truss, lattice, girder, trestle, arch, cantilever, suspension, pontoon, etc. On a basis of operation, bridges may be classified as draw, swing, lift, bascule, etc. A trestle bridge is commonly spoken of merely as a trestle.

Bridges must be designed for dead load, live load and impact. The dead load is the entire weight of the suspended structure. The live load now commonly used is one of Cooper's loading series. Cooper's class E-50 loading is for two coupled consolidation locomotives with tenders, followed by a uniform load. The loads for each locomotive are 25,000 lb. on the truck axle, 50,000 lb. on each of the four driving axles and 32,500 lb. on each of the four tender axles. The uniform load is 5000 lb. per linear foot. The truck axle is 8 ft. ahead of the front driving axle; the driving axles are spaced 5 ft. center to center; the forward tender axle is 9 ft. back of the rear driver; the spacing of tender axles is 5, 6 and 5 ft.; the truck axle of the second locomotive is 8 ft. behind the rear axle of the first tender; and the uniform load is 5 ft. behind the rear axle of the second tender. Cooper's class E-55, class E-60, and class E-65 provide for heavier loading. The weights of each class are proportional to the class number; thus the weights of class E-55 are $^{11}\!/_{10}$ those of class E-50, those of class E-60 are $^{12}\!/_{10}$ those of class E-50, etc. The spacing of loads is the same for each class.

The common formula for impact is

$$I = S\frac{300}{L + 300}$$

where I = impact stress to be added to live-load stress, S = computed maximum live-load stress for each member, and L = loaded length of track in feet producing the maximum stress in the member. For bridges carrying more than one track, the aggregate length of all tracks producing the maximum stress must be used.

The carrying capacity of a bridge is the heaviest live load which may pass over it in regular service without subjecting the structure to such severe stresses as to impair its strength. The carrying capacity of a bridge slowly decreases as the structure deteriorates with age. The bridges on each operating division should be classified for operating purposes according to their carrying capacity. This is done by analyzing the structure and determining the class of loading which it is capable of carrying. The weakest structure on any division fixes the maximum weight of engine which can be used over that division. A skeleton map showing each division of the entire railway system should be prepared, and a figure should be placed on each division, showing the maximum weight of engine which the weakest structure will carry. As the old structures are renewed or replaced the figures must be revised accordingly.

206. Protection of Iron and Steel Structures.—The method universally used to protect iron and steel structures from corrosion is painting. Protection by means of an encasement of concrete has been tried in a few cases and with satisfactory results, but the method is quite expensive. Existing steel structures can be thus protected by covering all surfaces with wire mesh and applying cement with a cement-gun. An encasement 3 in. in thickness applied in this way costs about 25 cts. per square foot of surface. The cost of a poured encasement of the same thickness is about the same. The blast of the locomotive exhaust does serious damage to the floors of low overhead structures of all kinds. A concrete encasement is rapidly worn away and unencased steel is rapidly eaten away by corrosion. If the floor is not encased in concrete, smoke-shields must be provided. Where the floor is encased in concrete blast-boards must be placed over the center of the track. These should be from 20 to 30 in. wide, depending upon the height above the track. The materials which have been used for blast-boards are chilled cast-iron plates, steel plates, glazed tile, asbestos board, and wood. Wood is rapidly worn away and requires frequent renewal.

Paints are made from a variety of materials and in many forms and combinations. Hence their relative efficiencies vary greatly. It has been demonstrated that certain pigments which possess excellent waterproofing properties, at the same time stimulate corrosion of iron or steel when applied to the bare surface. Because of this, pigments may be divided into those which retard corrosion, and those which exclude air and moisture. The fact that most commercial paints possess both of these properties to some degree accounts for the fact that the performance of a paint is different under different atmospheric and climatic conditions. Red lead mixed with pure linseed oil is a good rust-retarding paint. A mixture of this, consisting of about 25 lb. of red lead to 1 gal. of linseed oil, often is kept in stock at the storehouse. A quantity of this is sent out when needed and is reduced in the field to the proper consistency at the time of application. The following is an abstract from the 1915 report of the Committee on Iron and Steel Structures, American Railway Engineering Association:

> Paints for the protection of iron and steel structures may be simple liquids, as drying oils; dissolved solids, as asphalt paints and coal-tar paints; combinations of pulverized or finely divided solids, known as pigments, and of drying oils, known as vehicles; and almost any combination of any of these. Varnishes are mixtures of gums and oils, compounded by means of heat, and are frequently introduced into the vehicles of paint. The most important and extensively used paints are those which are mechanical mixtures of pigments and vehicles. Linseed oil is the most important and common vehicle. Other vehicles are (*a*) mineral oils, (*b*) fish oils, (*c*) china wood oil, and (*d*) soya bean oil. All of these but (*d*) have been used as cheap and inferior substitutes for linseed oil, though each is useful in certain paints. Turpentine, benzine, benzol, naphtha, etc., are used as thinners and solvents. A dryer is generally a liquid which, when incorporated into a paint, causes the film of paint to dry by oxidation with the required rapidity. The most durable paints are those which are composed of pigments with linseed oil as the chief ingredient of the vehicle. Open-kettle-boiled linseed oil is used mostly for metal-paints. Pigments are classed as primary and secondary. Primary pigments are strong in color and covering power, while secondary pigments are weak in this respect and generally should not be used alone. The principal primary pigments used for structural-metal paints are white leads of the basic carbonate and sulphate varieties; zinc oxide; red lead; blue lead; Venetian red and other iron oxides; lampblack; carbon blacks; graphite; ochres; natural carbons, slates, clays, etc.; and chrome greens and yellows. The principal secondary pigments are silica; asbestine; natural and artificial sulphate of barium; calcium carbonate; clays and gypsum. The cost of primary pigments usually ranges from 2 to 10 cts. per pound, except for chrome, which is quite expensive when pure. The cost of secondary pigments usually is less than 2 cts. per pound.

207. Solid-floor Bridges.—Steel bridges are built with solid, water-tight floors for two primary purposes: (1) to prevent water, oil, ashes, or any other material from falling to a street below, and (2) to allow the standard ballasted track to be carried across the bridge. Other resulting advantages are a reduction of noise, and a reduction of danger from electrolysis. The second primary purpose could be accomplished by using any solid floor of wood or other material but this would tend to hold water around the metal parts of the floor and hasten corrosion. Hence for whatever purpose the solid floor is used it should be waterproof. To waterproof successfully a floor other than of reinforced concrete is a difficult problem. It is more difficult to waterproof half-through structures than deck-structures, because of the joint between the waterproofing and the girder. The bridge-floor may be built of creosoted timber, steel, reinforced concrete, or concrete and steel. The materials used for waterproofing are asphalt, tar, or several layers of felt mopped with one of these. A layer of concrete or brick may be placed over the water-proof membrane to protect it from injury, such as might result from tamping of the ballast. Besides imperviousness, the most important feature of the waterproofing material is elasticity, so that it will not be cracked by expansion and contraction of the bridge. The surface to be covered should contain no sharp projecting points, and all metal surfaces to be covered should first be thoroughly cleaned of all dirt, rust, and scale. The water-proof membrane should be laid with a pitch of about 1 in 75 from the side to the center and weep-holes should be provided at frequent intervals, the object being to get rid of the water as quickly as possible.[1]

Reinforced-concrete floors ordinarily are not waterproofed, as the thick layer of concrete is more or less effective as a waterproofing. Two types of unwaterproofed reinforced-concrete floors for steel bridges are shown in Fig. 155. That shown at (*A*) is a double-track concrete girder; (*B*) is for a through, steel-girder bridge.

The danger of the destruction of timber bridges by fire makes some form of fireproofing almost a necessity, and in certain places such is required by law. Most fires on bridges start from sparks or coals from locomotives. Occasionally the fire starts from an outside source, but besides keeping all vegetation away from the bridge it is hardly necessary to fireproof for such a cause. Almost all fires caused by locomotives can be prevented by using any good type of fireproofing. Fireproofing of bridges is most necessary on high-speed lines and where the bridge is hid from view of the engineman until the train is almost upon it. The following types of fire-proof construction may be used: (1) Ballast-floor structures, the standard ballasted track being carried across the bridge as on an embankment. (2) Covering the ties, or the caps and stringers—preferably both—with sheets of metal. (3) Placing a wood filler between the ties and covering ties and fillers with from 2 to 4 in. of ballast. The following types of semi-fireproof construction may be used: (*a*) Timber bents carrying I beam stringers. (*b*) Ordinary timber trestles built of certain kinds of treated timber. (*c*) Fire-resisting paints. A ballasted floor is an effective fireproofing but there are also other advantages gained by this type of construction. These are discussed in the following article.

When the ties, caps, and stringers are covered with metal, galvanized iron, about No. 20 or No. 22 gage, is used. The metal must be securely fastened to the timber. Metal coverings for caps and stringers also increase the life of the timber by protecting it from moisture, but inspection

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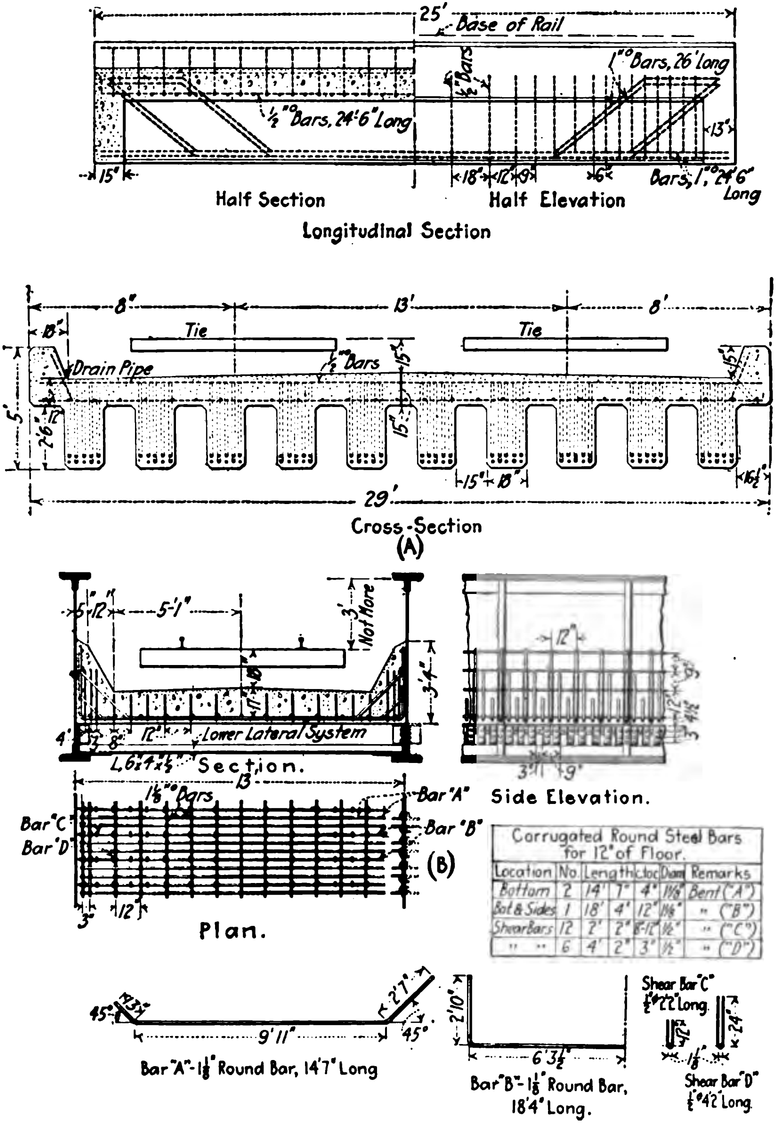
[1] See "The Waterproofing of Solid Steel-floor Railroad Bridges," by S. T. Wagner, and subsequent discussions, Vol. 78, Transactions, Am. Soc. C. E.



Corrugated Round Steel Bars for 12" of Floor.

Location	No.	Length		c.to c.	Diam.	Remarks
Bottom	2	14'	7"	4"	1⅛"	Bent ("A")
Bot & Sides	1	18'	4"	12"	1⅛"	" ("B")
Shear Bars	12	2'	2"	8"-12"	½"	" ("C")
" "	6	4'	2"	3"	½"	" ("D")

FIG. 155.—Concrete floors for bridges.

and repairs are more difficult. A shallow covering of ballast over the ties and fillers is a good fireproofing as long as the timber is kept covered. However, vibration tends to cause the ballast to shift and collect over the more rigid parts of the structure, and unless constant care is exercised, the timber will become exposed in places. The ballast also holds moisture and the timbers decay more rapidly. The results are best if the top of the fillers is about an inch below the top of ties. The fillers extend from guard-timber to guard-timber. With 3 in. of gravel over the fillers this type of construction costs from 35 to 40 cts. per linear foot of track.

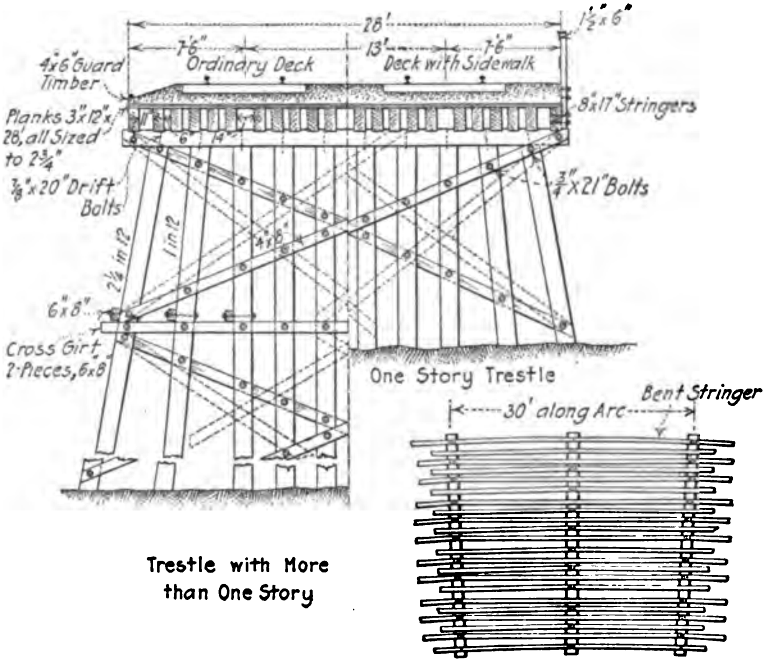
The use of treated timber adds from $1.00 up per linear foot to the cost of the trestle. Hence this type of construction should never be used solely as a fireproofing, as other more efficient methods are cheaper. The principal advantage gained is longer life resulting from slower decay. The use of treated timber in trestle-construction has been discussed in Art. 95. Ties treated with zinc chloride appear to ignite less readily than untreated ties. Creosoted ties appear to ignite more readily than untreated ties, and burn more fiercely, but the depth to which the wood is burned is less than in untreated timber.

Several railways in Canada and in the Eastern States have used fire-resisting paints with good results. It is much cheaper in first cost than other fireproofing methods but must be repeated at intervals of about 5 years. The paint should be applied to the tops of all caps and stringers, and to the tops and sides of ties. It is beneficial also in keeping moisture from entering the wood at a most important place. The Delaware and Hudson, Erie, Maine Central, Boston and Maine, Canadian Pacific, etc., have used fire-resisting paints to some extent, Clapp's Fire-resisting Paint being used in most cases.

The Board of Railway Commissioners of Canada requires every steam-railway operating across wooden trestles, the whole of which cannot be seen from an approaching train for a distance of at least 1000 ft., to have each such structure inspected by a watchman at least once every 8 hours during the months of May to October, or to protect all such bridges either with fire-alarm signals, ballast flooring, zinc covering of caps and intersections, or fire-proof paint.

Water-barrels should be maintained on all trestles irrespective of fireproofing. If the trestle is over 30 ft. long a barrel should be placed at each end. On long trestles barrels should be placed at intervals not exceeding 150 ft.

208. Types of Ballast Decks for Trestles.—There are two general types of construction of ballast-deck wooden trestles: (1) the stringers being separated and covered with plank to retain the ballast; (2) the stringers being placed in contact, so as to form a solid floor which directly carries the ballast. These two types are shown in a general way in Fig. 110. The distance from center to center of bents and the number of piles or posts per bent is the same as for open-floor construction, which is discussed in Art. 210. It is very important that all timbers in trestles of this character be treated. The oldest creosoted ballast-deck trestles have been in service about 18 years and only minor renewals have been necessary. The life of these structures is estimated to be from 20 to 25 years, depending largely on climatic conditions. The open-stringer type requires deep stringers. This type of construction is economical in districts where deep stringers can be obtained at a reasonable cost. Less timber is required than for a solid-stringer deck, drainage is better, and inspection and renewal are easier. The solid-stringer floor is economical where large timbers cannot be obtained at a reasonable price, necessitating the use of shallow stringers and short spans. The cost of ballast-deck trestles is from 40 to 50 per cent. of that of reinforced-concrete trestles. The details of the standard double-track ballast-deck trestle of the Union Pacific and Southern Pacific is shown in Fig. 156. The dotted lines of the bracing are used when the long pieces cannot be obtained readily. Only the piles and caps are treated. All other timber is untreated pine. A water-proof layer of prepared roofing is laid on top of the plank floor. For drainage purposes the floor of the trestle is given a circular crown of 1 in., across the track. This is done by sawing the tops of piles to the desired radius. Sway-bracing is omitted



Trestle with More than One Story

One Story Trestle

Arrangement of Stringers For Curved Track

FIG. 156.—Open-stringer-floor type of ballast-deck trestle.

when the bent is less than 10 ft. high. A single-track open-stringer type of trestle is shown in Fig. 157.

The advantages of ballast-deck trestles are long life; low cost of maintenance; continuous roadbed; easier-riding track; track which can be surfaced and lined by section labor; greater safety in case of derailment; and decreased danger of fire. The disadvantages are higher first cost which, with treated floor timbers, is about 75 per cent. more than for the open-floor trestle; difficulty of inspection; difficulty of making renewals, and excessive cost of same when necessary.

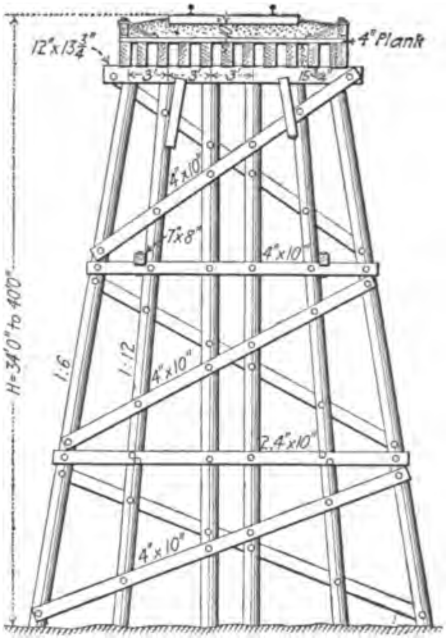


Fig. 157.—Open-stringer ballast-deck trestle; six-pile bent.

209. Superelevation on Bridges.—Curves on bridges should be avoided where possible during location. When it is impossible to avoid placing a curve on a bridge, the structure must be made strong enough to withstand the stresses resulting from all speeds between zero and the maximum possible at that point. The principal difference in design is in providing for the superelevation. This can be done in a number of different ways. Referring to Fig. 158, some of the most common methods used to provide the superelevation are as follows: (1) By placing a wedge under the outer edge of each tie, thus keeping the caps and stringers horizontal but inclining the ties, as at (*A*). Each wedge must be bolted to the tie. This method is one of the most satisfactory, as the tie is the only timber dapped and its strength is but slightly affected by so doing. However, relining track is almost impossible. (2) By maintaining the caps, stringers, and ties horizontal and placing a wedge on top of the tie under the outer rail and guard-timber, as at (*B*). This method is similar to (1). (3) Maintaining the caps horizontal and placing a wedge under the stringers, thus inclining the stringers and ties, as at (*C*). This has the advantage that none of the ties or bridge-timbers are notched, but there is a tendency for the stringers to overturn when the speed of train is less than provided for by the superelevation.

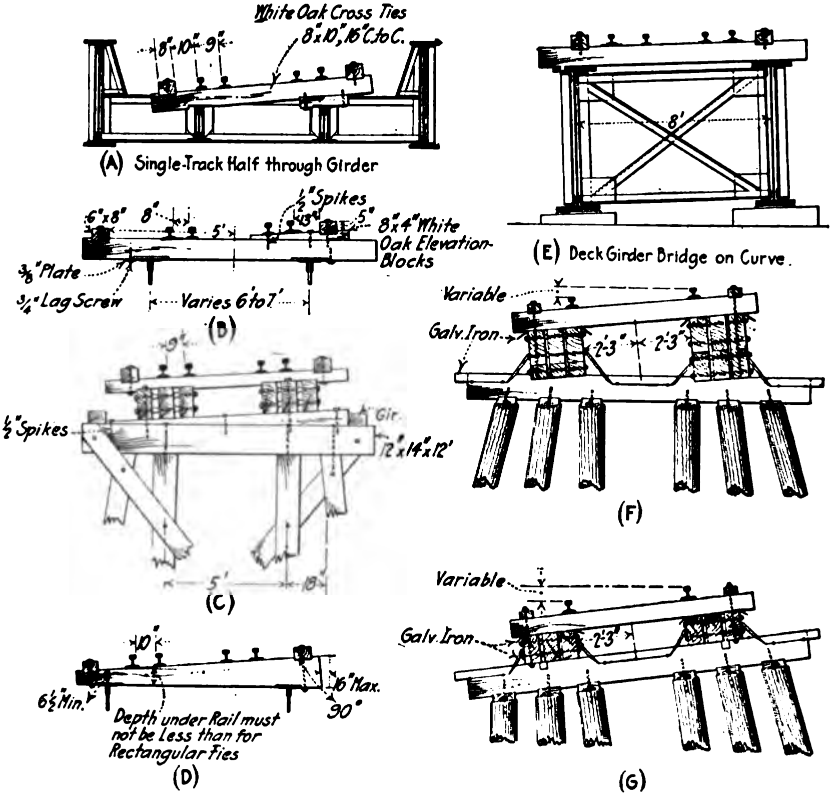


Fig. 158.—Superelevation on bridges.

(4) Using wedge-shaped ties on horizontal caps and stringers, as at (*D*). The ties must be cut from large timbers and more timber is required than in (1) or (2) but the construction is simpler than in any of the first three methods. (5) Elevating the girders of a deck-girder bridge by using wedge-shaped bearing blocks under the bed-plates, as at (*E*). This method should be used only where the required superelevation is small, as the inclined girders are subject to unknown stresses when under load. (6) Maintaining the caps horizontal and using inclined stringers resting on inclined bolsters or corbels of different depths under each rail as at

(*F*). This exaggerates the tendency of the outer stringers to overturn. (7) Changing the general arrangement of the bent by changing the inclination of all piles or posts, thus inclining the entire floor structure, as at (*G*). The superelevation on a ballast-deck trestle is obtained by elevating the outer rail in the ballast as on ordinary roadbed.

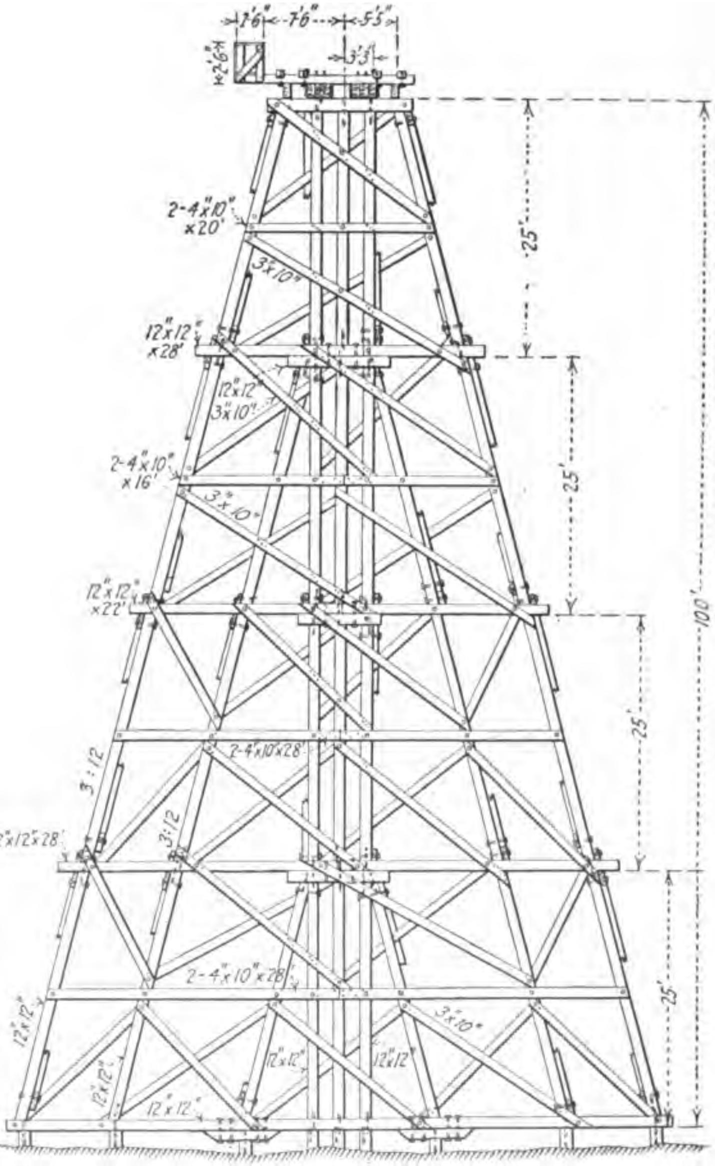


Fig. 159.—One-hundred-foot bent of a high frame trestle; N. T. R.

On all curves where the posts of a bent are symmetrical about the vertical axis the lateral bracing must be made extra heavy, and it must be seen that, for the highest speeds, the line of the load-stress does not fall too near the outer end of the sill.

210. Pile and Frame Trestle Bridges.—Trestles may be classified according to form of bents as pile trestles and frame trestles. The bents of a frame trestle are constructed of sawed timbers; they support caps and rest on sills. Each sill should rest on pile or masonry footings, though timber mud sills are sometimes used. Pile trestles consist of a group of piles driven in the form of a bent, each bent supporting a cap. The height of a pile trestle is limited by the length of piles, and usually does not exceed 35 ft. above the ground. For low trestles, particularly across sluggish bodies of water, pile trestles are the most economical form of temporary structure. For heights up to 50 ft. the number of posts per bent for both pile and frame trestles is 4, 5, or 6 for single track, and from 7 to 11 for double track. Greater heights require additional posts of intermediate heights as shown in Fig. 159, which is one bent of a high frame trestle of the National Transcontinental Railway. The bent in the illustration has 5 full-length posts and two pairs of shorter posts. The standard 4-post frame trestle has the two center posts vertical and the two outer posts inclined, as shown in Fig. 160. The same arrangement may be used for a pile trestle, or the 4 posts of a low pile trestle may be vertical. A 5-post bent with the three inside piles vertical is shown in Fig. 161 and a 5-post frame bent with the center post vertical is shown in Fig. 162. Either 2 or 4 posts of a 6-post bent are inclined. The majority of railways incline 4 posts, as shown in Fig. 157.

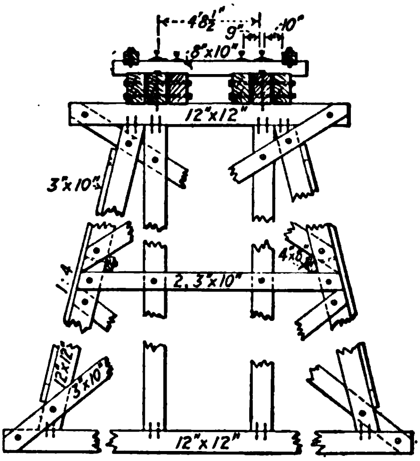


Fig. 160.—Frame trestle; four-post bent.

The sizes of caps are 12 by 12 in., 12 by 14 in., 12 by 18 in., and 14 by 14 in.; and the length is usually 12, 14, or 16 ft. for single track. The average life of unprotected caps is about 10 years. Two, three, or four stringers are laid under each rail. The three-stringer construction is shown in Figs. 158, *C*, *F*, and *G*, 160 and 162. Four stringers under each rail are shown in Fig. 161. The Seaboard Air Line uses 7- by 14-in. stringers having a span of 12 ft. 6 in.; two stringers per rail are used on lines carrying engines weighing less than 60 tons; three stringers per rail are used for engines weighing over 60 and less than 90 tons; and four stringers per rail are used for heavier engines. A few railways place an additional stringer under the center of the track, and a few others place

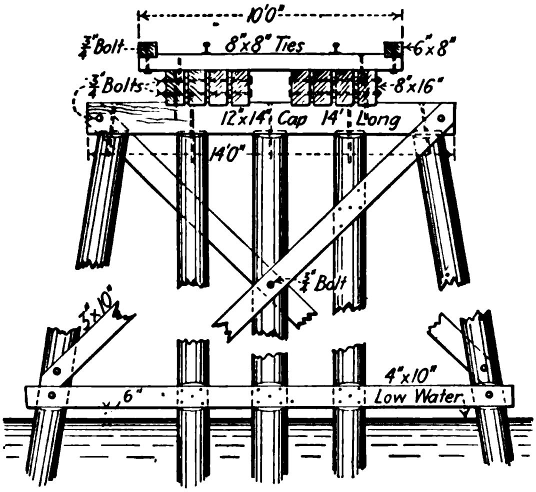
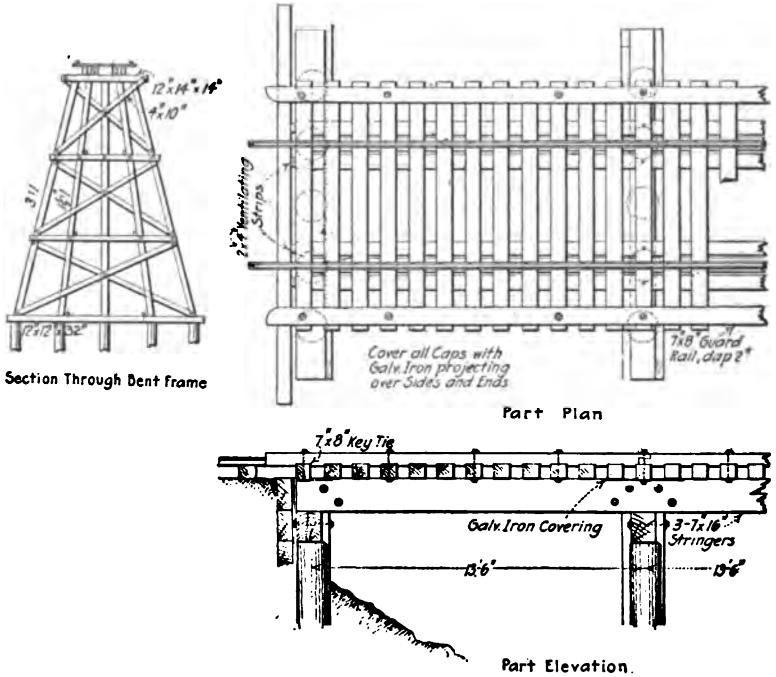


FIG. 161.—Pile trestle; five-pile bent.



Section Through Bent Frame

Part Plan

Part Elevation.

FIG. 162.—Frame trestle; five-post bent.

an outside stringer near the end of each tie, as shown in Fig. 159. The size of stringers ranges from 7 by 15 in., to 8 by 20 or 9 by 18 in., and a few roads use odd sizes such as 10 by 16, 12 by 14, or 12 by 16 in. The stringer should be long enough to reach two spans. The length of span ranges from 12 to 16 ft., the shorter span being more common. The average life when unprotected is about 10 years. The number and size of stringers must be determined from the maximum bending moment due to the heaviest engine, allowing about 50 per cent. for impact. The two species of timber in general use for caps and stringers are long-leaf yellow pine and Douglas fir.

Two common types of longitudinal bracing are shown at (*A*) and (*B*), Fig. 163. Several railways use a bracing similar to that at (*A*) but with diagonals only in every second or third span, the horizontals being maintained the same.

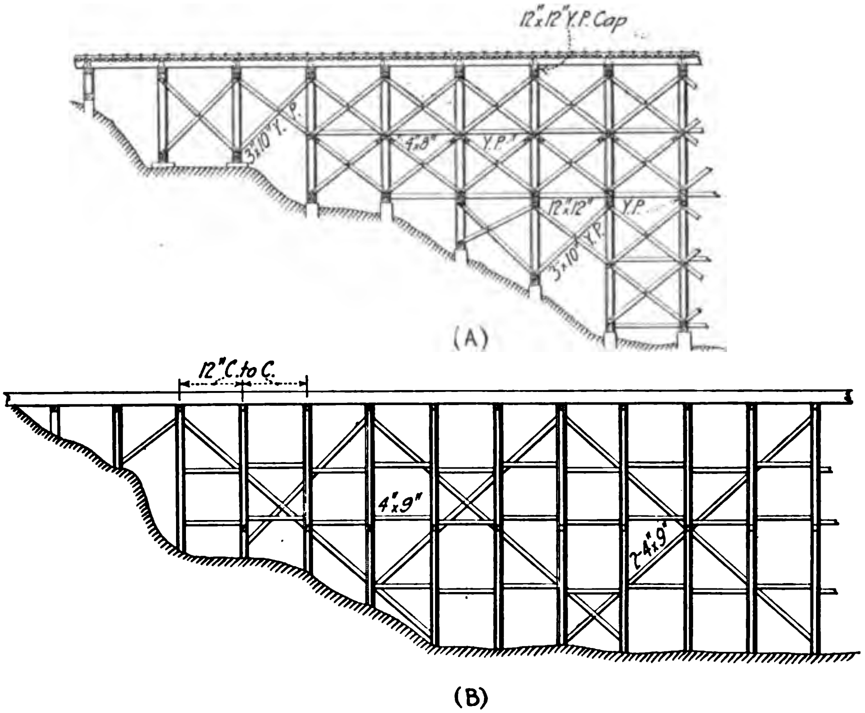
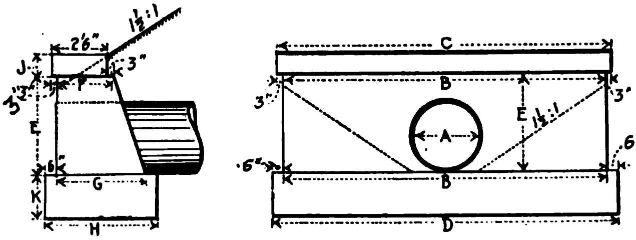


Fig. 163.—Longitudinal bracing for trestles.

It is usually economical to maintain bridges and trestles by renewing individual parts until the general condition of the structure is such that the cost of yearly renewals is greater than the interest on a new structure. When this occurs the structure should be renewed entirely.

On several railways trestles with concrete bents of a monolithic structure have been used, but only in a few cases have concrete piles been used in railway trestle-construction. Several such structures have been built by the Chicago, Burlington and Quincy Railroad, the bents being placed 14, 15, or 16 ft. center to center. Each bent consists of six concrete piles driven in the ordinary way with a hammer. These support a concrete cap which is cast in place. Upon the caps rest two girder slabs for each span. Longitudinal rigidity of long trestles is obtained by making each sixth bent double. The piles have not been used in trestles over 18 ft. in height. The cost is about $30 to $35 per linear foot for single track.

211. Pipe Culverts.—A culvert is a covered drain carried under the roadbed for the passage of water. Culverts may be classified according to form as pipe, box, arch, and tunnel. Pipe culverts consist of one, two, or three adjacent lines of circular jointed pipe made of vitrified clay, cast iron, corrugated iron, or concrete. Reinforced-concrete pipe is used in sizes ranging from 12 to 72 in. in diameter, and costs from 25 to 50 per cent. less than cast-iron pipe of the same diameter.



DIMENSIONS OF HEADWALLS.

A	B	C	D	E	F	G	H	J	K	L	M	N
INSIDE DIAMETER OF PIPE.	LENGTH OF HEADWALL UNDER COPING	LENGTH OF COPING OVER ALL	LENGTH OF FOUNDATION	HEIGHT OF WALL UNDER COPING	WIDTH OF WALL UNDER COPING	WIDTH OF WALL AT NEAT LINE	WIDTH OF FOUNDATION	THICKNESS OF COPING	DEPTH OF FOUNDATION	CONTENTS OF HEADWALL IN CUB. FT.	CONTENTS OF HEADWALL & COPING IN CUB. FT.	CONTENTS OF FOUNDATION IN CUB. FT.
12"	6'-3"	6'-9"	7'-3"	2'-3"	2'-6"	3'-4"	4'-4"	12"	2'-0"	38.12	54.99	62.78
18"	8'-3"	8'-9"	9'-3"	2'-9"	2'-6"	3'-6"	4'-6"	12"	2'-0"	61.73	83.60	83.25
24"	10'-3"	10'-9"	11'-3"	3'-3"	2'-6"	3'-8"	4'-8"	12"	2'-0"	92.35	119.22	105.07
30"	12'-3"	12'-9"	13'-3"	3'-9"	2'-6"	3'-10"	4'-10"	12"	2'-0"	127.75	159.62	128.07
36"	14'-3"	14'-9"	15'-3"	4'-3"	2'-6"	4'-0"	5'-0"	12"	2'-0"	170.45	207.32	152.50
40"	15'-3"	16'-1"	16'-7"	4'-7"	2'-6"	4'-1"	5'-1"	12"	2'-0"	201.71	241.92	168.53
42"	16'-3"	16'-9"	17'-3"	4'-9"	2'-6"	4' 2"	5'-2"	12"	2'-0"	220.76	262.63	178.24
48"	18'-3"	18'-9"	19'-3"	5'-3"	2'-6"	4'-4"	5'-4"	12"	2'-6"	277.38	324.25	256.60
54"	20'-3"	20'-9"	21'-3"	6'-3"	2'-6"	4'-6"	5'-6"	12"	3'-0"	378.77	430.64	350.62
60"	22'-3"	22'-9"	23'-3"	7'-0"	2'-6"	4'-8"	6'-0"	12"	3'-0"	476.98	533.85	418.50

FIG. 164.—Head-walls for pipe culverts.

Every pipe culvert should be protected at both ends by brick, stone, or concrete head-walls. Wing-walls in addition, are desirable for large pipes. The pipe should be laid in an excavated trench and to a perfect line and grade. Settling causes the pipes to pull apart and the entire culvert may stretch or lengthen. Some engineers advocate laying the pipe with uncalked joints, believing that this assists in draining the fill. Other engineers believe the culvert should be watertight, to prevent saturating the bottom of the fill. If the pipe is laid with uncalked joints a slight camber may be given the culvert. Any slight settlement of the central portion will then be taken up by the camber. A rectangular wall is the simplest form of head-wall. The apron should extend from 2 to 3 ft. below the pipe, to prevent undermining. A standard form of head-wall is shown in Fig. 164, with an accompanying table of dimensions and quantities.

Pipes should be used only where the foundation is unyielding. The top of the pipes should be not less than 12 in. below the top of roadbed. There is considerable difference of opinion as to the depth at which pipes of different materials can be used safely. The pressure on a pipe under a high fill is very great and has been known to split a cast-iron pipe under a 65-ft. fill. It is very difficult to repair a culvert in which some of the joints have opened or a pipe has broken. Excavating the pipe or tunneling must be resorted to if the pipe is broken. In some cases opened joints can be closed by running a rod through the culvert, fastening the ends of the rod to timbers across the ends of the culvert and by tightening up on the pipe, by means of a turnbuckle in the rod, the joints are drawn together.

212. Arch Culverts.—Arch culverts now are usually constructed of plain or reinforced concrete. In some cases they are faced and lined with brick or masonry. A 25-ft. arch built of masonry or with masonry walls and brick ring is shown in Fig. 165. The details of a 4-, 6-, 8-, and 10-ft. reinforced-concrete arch culvert are shown in Fig. 166. Many railways use plain concrete for spans of considerable length. The details of a single and a double plain concrete arch used by the Pennsylvania Railroad for spans from 10 to 80 ft. are shown in Fig. 167. The arch and spandrels should be constructed in monolithic sections the joints of which are shown on the cross-sections and plan. The dimensions for different spans are given by the following formulas:

H = height of wing-walls in feet,

M = rise of arch in feet, which should be not less than $\frac{S}{5}$,

S = span in feet,

$$R = \text{radius in feet} = \frac{S^2}{8M} + \frac{M}{2}, \qquad (212a)$$

A = thickness in feet at springing line,

$$= \frac{3R}{10} + 3, \text{ for semicircular arches}, \qquad (212b)$$

$$= \frac{R}{5} + \frac{M}{10} + 4, \text{ for segmental arches}, \qquad (212c)$$

K = thickness in feet at crown,

$$= \frac{\sqrt{R}}{2} + 0.25, \text{ but must be not less than 18 in.}, \qquad (212d)$$

$$B = \frac{M + K}{2}. \qquad (212e)$$

When staking out a culvert or when computing volumes, etc., it is necessary to know the exact horizontal distance, from the center line of the track, in which the grade of the floor of the culvert will intersect the wing-walls. This distance will be different on the upper and lower sides. Referring to Fig. 168, the distance on the low side is given by,

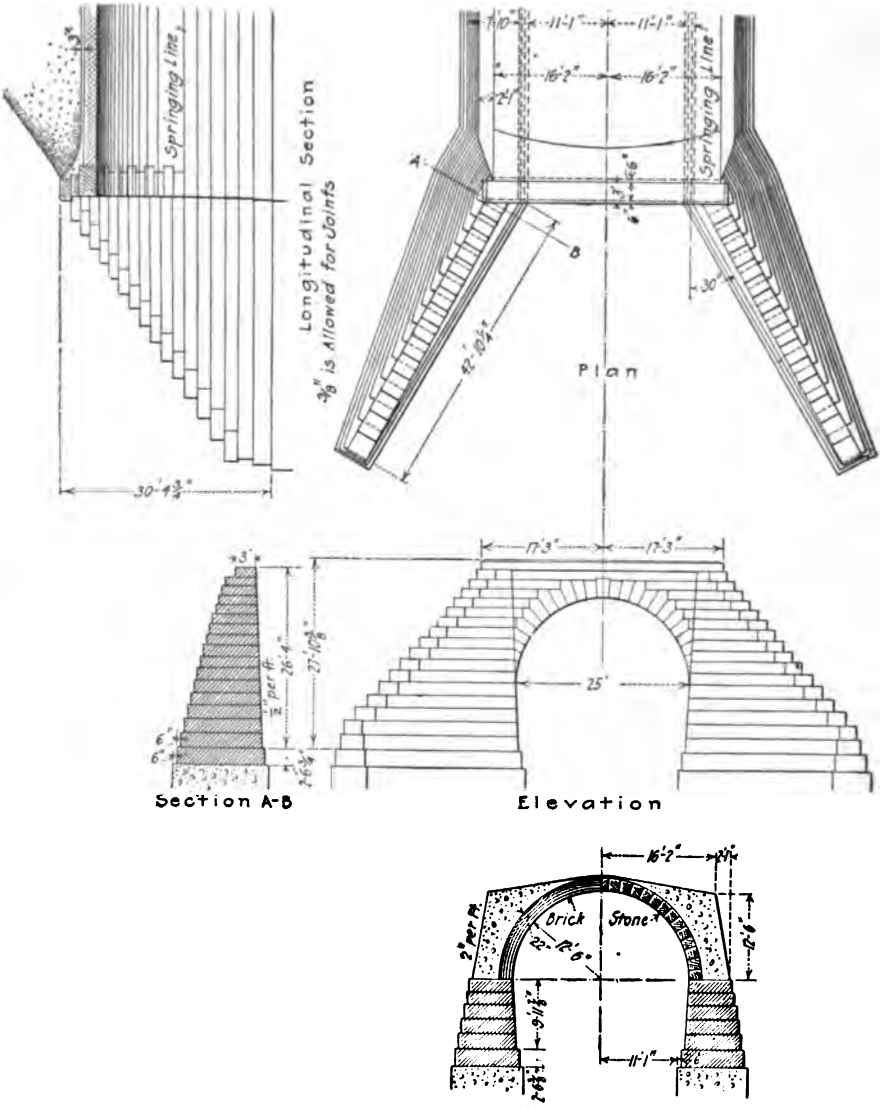
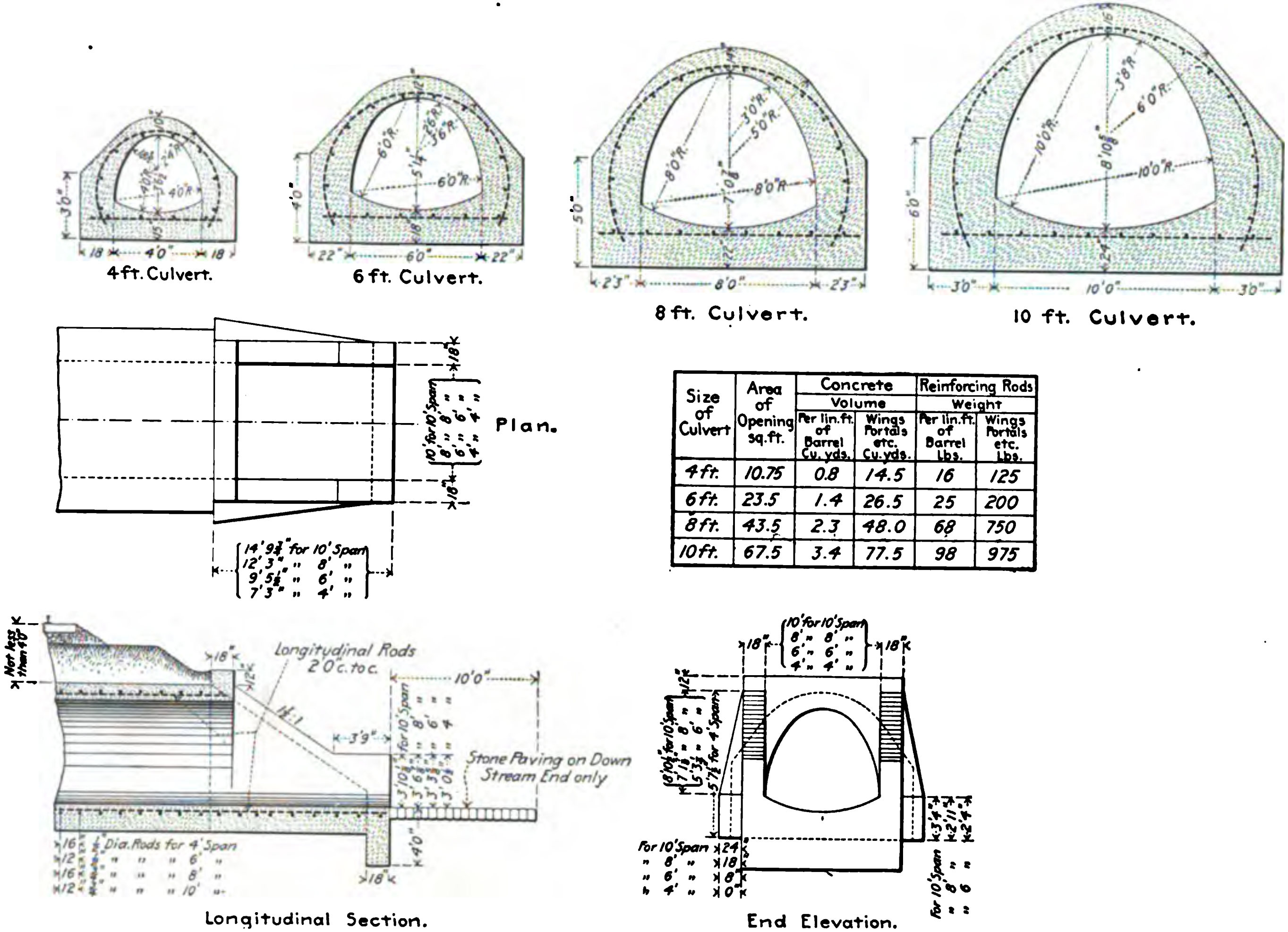


FIG. 165.—Masonry and brick arch culvert.

$$y = \frac{c \tan A}{\tan A - \tan B} \qquad (212f)$$



Size of Culvert	Area of Opening sq. ft.	Concrete Volume Per lin. ft. of Barrel Cu. yds.	Concrete Volume Wings Portals etc. Cu. yds.	Reinforcing Rods Weight Per lin. ft. of Barrel Lbs.	Reinforcing Rods Weight Wings Portals etc. Lbs.
4 ft.	10.75	0.8	14.5	16	125
6 ft.	23.5	1.4	26.5	25	200
8 ft.	43.5	2.3	48.0	68	750
10 ft.	67.5	3.4	77.5	98	975

FIG. 166.—Reinforced-concrete arch culverts.

or, expressed as a rule, multiply the horizontal distance for a level grade by the tangent of the angle of inclination of the wing-wall from the horizontal, and divide by the difference of the tangents of the inclination from the horizontal of the wing-wall and the grade of the culvert. For the up-grade side divide by the sum of the tangents, or

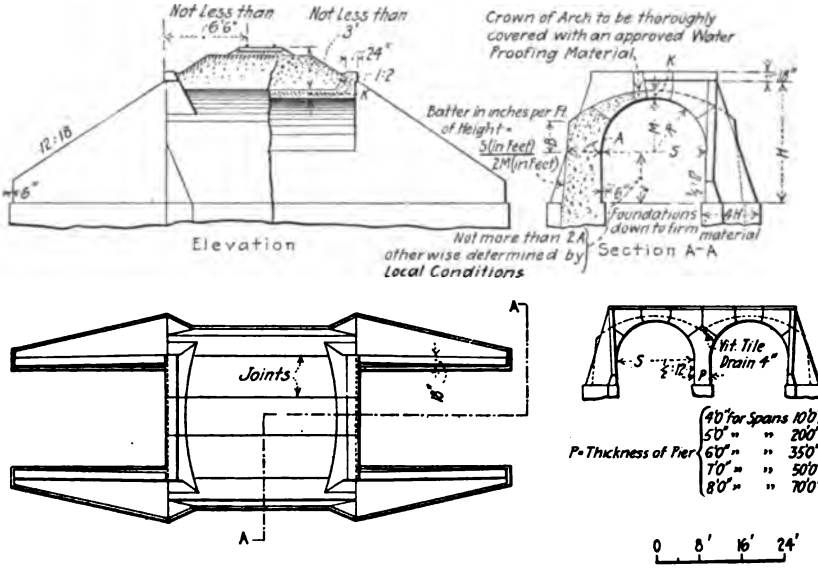

Not Less than 6'6"
Not Less than 3'
24"
1:2
K
12:18
6"
Elevation
Crown of Arch to be thoroughly covered with an approved Water Proofing Material.
K
18"
Batter in inches per Ft of Height = S(in Feet) / 2M(in Feet)
A
S
R
H
6"
Foundations down to firm material
4H
Not more than 2A otherwise determined by Local Conditions
Section A-A
Joints
A
A
S
12
P
Vit. Tile Drain 4"
P = Thickness of Pier
4'0" for Spans 10'0" to 20'0"
5'0" " " 20'0" " 35'0"
6'0" " " 35'0" " 50'0"
7'0" " " 50'0" " 70'0"
8'0" " " 70'0" " 80'0"
0 8' 16' 24'

FIG. 167.—Plain concrete culverts for spans up to 80 ft.

$$y = \frac{c \tan A}{\tan A + \tan B} \qquad (212g)$$

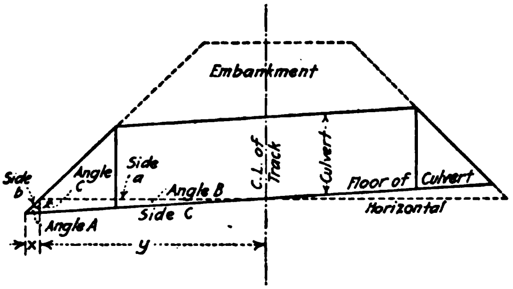


FIG. 168.—Length of culverts.

Tunnel culverts are economical only in special cases. If the embankment is high and on one side starts from a narrow shoulder of the hill, a small tunnel may be economical if the length is less than that required for a culvert, and if the rock can be worked easily but is not liable to cave. There are several advantages of this method. Water is kept entirely away from the embankment and there is no trouble from poor foundations or a settling fill.

213. Box Culverts and Open Drains.—Box culverts are built of timber, masonry, reinforced concrete, or a combination of any of these, concrete generally being used in recent construction. A small masonry box culvert has masonry walls and a flat top composed of stones sufficiently large to span the opening. Larger masonry box culverts have the top formed in steps. The invert of a box culvert may be either flat or a segment of a circle. Timber culverts are short-lived and should be avoided. When used under high embankments they should be constructed of such size as to admit iron or concrete pipe of the necessary dimensions to be laid inside the culvert when renewal becomes necessary. A culvert consisting of masonry or concrete abutments and a creosoted timber top gives good service. A rail-top culvert is a box culvert having masonry or concrete abutments and a top consisting of old rails laid close and embedded in concrete, as shown in Fig. 169. If the span is long, several additional rails are inverted and placed between the culvert-rails under each track-rail.

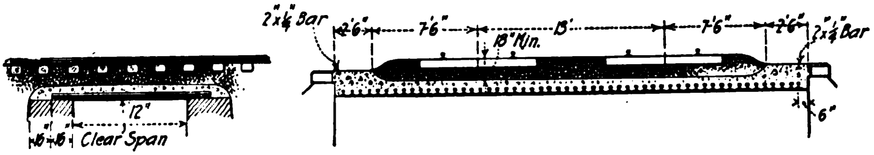
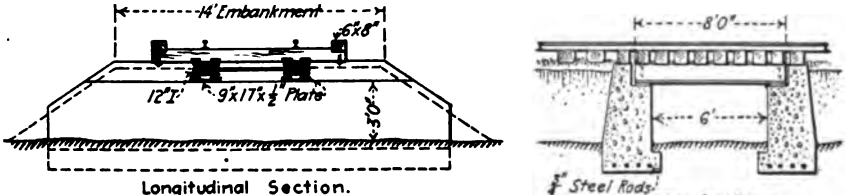
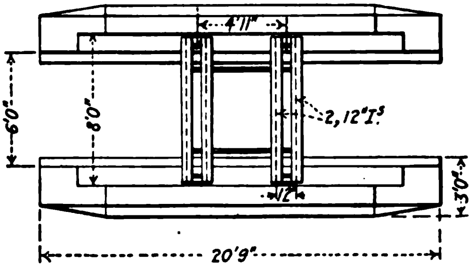


Fig. 169.—Rail-top culvert.



Longitudinal Section.

Cross Section.



Plan.

Fig. 170.—Open drain.

When the bottom of a small drainage channel is not far enough below the bottom of the ties to secure the proper size of opening by using some kind of culvert, open drains are resorted to. If an opening is sufficient which is less in width than the distance between two adjacent ties, an open-top concrete box can be built under the track and the ties on each side placed on the abutments. This requires no additional supports for the track. If an opening of width greater than the clear spacing of ties is necessary, the ties must be supported by stringers spanning the opening. Wooden stringers may be used but they must necessarily be deep and if the headroom is limited they will be objectionable. When maximum headroom is required I beams should be used. An open drain having a span of 6 ft., built by the Virginian Railway, is shown in Fig. 170. Two 12-in. I beams resting on concrete abutments are placed under each rail. The foundations of the abutments are reinforced with ¾-in. steel rods when not resting on solid rock.

CHAPTER XVI

SWITCHES, FROGS, AND TURNOUTS

214. Switches.—A switch is a device consisting of two movable rails, with the necessary fastenings, connections, and operating parts, designed to turn a train from the track upon which it is running. In general, switches may be classified as stub, split or point, and those which allow continuous main-track rails. The stub switch has entirely disappeared from all main-line track and is installed only occasionally in little-used sidings or in industrial railways. It consists of two standard-length rails which are spiked to the ties only for part of their length. The ends toward the turnout are free to move and are connected to the switch-stand. When the switch is closed the rails are in line with the main-track rails beyond. When the switch is open the free ends are sprung 4 or 5 in. laterally to coincide with the rails of the turnout. The movement is limited by stop-blocks. The movable length of the rails depends on the degree of curvature of the turnout curve. A general rule which applies for No. 4 to No. 9 frogs, inclusive, is to make the movable length of throw-rail in feet equal to two less than three times the frog number. The movable length for a No. 6 frog would be $3 \times 6 - 2 = 16$ ft. The ends of the fixed turnout and main-track rails are held in place by a head-chair which is spiked to the head-block of the switch. Temperature expansion or creeping rails may jam the movable rails against the fixed rails, and contraction will increase the gap between the ends making a rough track and causing the rails to be injured by the wheels.

215. Split-switches.—At a split-switch the outer main-track rail is continuous through the switch and the inner rail is continuous into the turnout. The essential parts of a split-switch are the two switch-rails or switch-points; tie-bars; heel joints; gage- and slide-plates; and head-rod. These parts are illustrated in Fig. 171, which shows the details of a standard 15-ft. split-switch. The throw-rod is a part of the mechanism through which the switch is thrown. The throw of the switch, or the lateral movement of the switch-rails at the head-rod, ranges from 3½ to 6 in., 5 in. being the standard. The following is the practice of several railways: Boston and Maine, 3⅞-in. throw; Pennsylvania, and Virginian, 4-in. throw; Norfolk and Western, Pennsylvania Lines West, Wheeling and Lake Erie, 4½-in. throw; Delaware, Lackawanna and Western, Erie, Northern Pacific, Nashville, Chattanooga and St. Louis, Wabash, Queen and Crescent, St. Louis and Southwestern, New York Central

Lines, Southern, 5-in. throw; Canadian Northern, 5¼-in. throw; Grand Trunk Pacific, 5¼- and 6-in. throw.

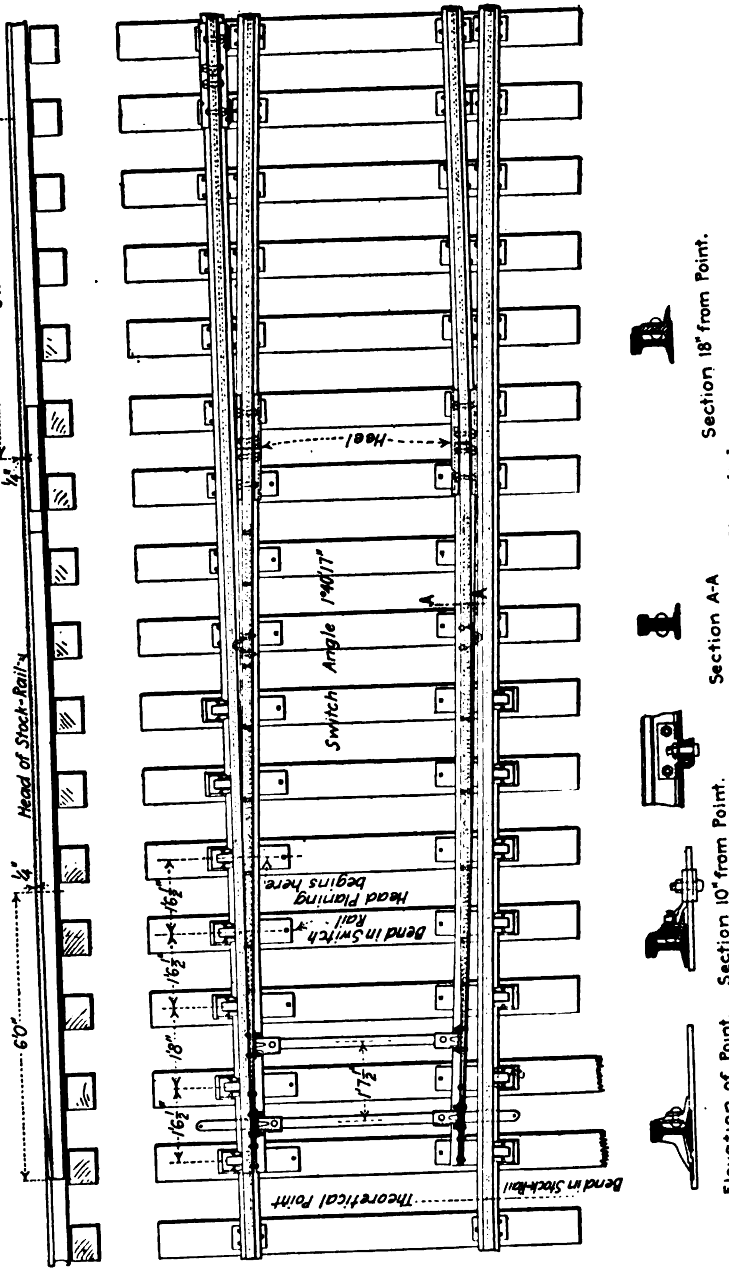


FIG. 171.—Fifteen-foot split-switch.

Each switch-rail is bent inward several feet back of the point and the outside of the head is planed to the web. On the inside the head and base are both planed. As the thin points of the switch-rails have little supporting power they are planed down below the top of the stock-rails. At a point where the width of each switch-rail has increased sufficiently to support the wheels, the switch-rail is raised slightly above the stock-rail and is maintained at this elevation to or beyond the heel of the switch. This is done to slightly lift the wheels from the stock-rail and prevent its being damaged by worn wheels. The heel-distance or spread at the heel, that is, the distance between gage lines of switch- and stock-rail at the heel of the switch, is from 5½ to 7½ in. Each switch-rail should be reinforced on each side with bars bent and planed to fit the web of the rail. The reinforcing bars extend from near the heel to the point and are bolted and riveted to the web of the switch-rail. The four cross-sections of the switch-rail in Fig. 171 show the reinforcing bars, which are also shown by dotted lines in the plan.

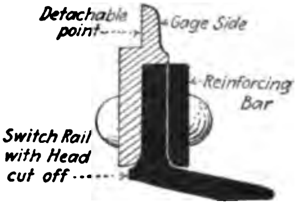


FIG. 172.—"Economy" separable switch-point.

Theoretically, the switch-rail is tapered to a point. This is not practicable and the actual point is several inches from the theoretical point and has a width of from ⅛ to ⅜ in. The inner stock-rail is bent at the theoretical point of switch. The switch angle is the angle between the gage lines of the switch-rail and main rail, and is fixed by three elements, spread at heel, length of switch-rail, and width at point. The spread at heel, less the width at point, divided by length of switch-rail, equals the sine of the switch angle.

Switch-points are subjected to severe service and must be watched constantly to see that they are not broken or damaged in a way which would catch a wheel-flange and cause a derailment. Several railways use switch-points made of manganese steel, but in some cases these have failed very rapidly by pieces being broken out of the point. In general the best service is obtained by using points made of high-grade ductile steel. These points do not break readily and adjust themselves to the worn conditions of the main rail. The renewal of almost all switch-rails results from worn or broken points. The "Economy" separable switch-point consists of a switch-rail in two parts. The head of the rail is cut away 3 or 4 ft. from the point and replaced with a bar resting on the web and having a flange which fits against the side of the web and takes the place of the ordinary reinforcing bar. The detachable point is held in place by bolts extending through its flange, the rail-web and the reinforcing bar on the opposite side. A cross-section of this switch-point is shown in Fig. 172. With a device of this kind the renewal of switch-points is comparatively simple.

A spring-switch, Fig. 173, is an ordinary split-switch having a stiff coiled spring which holds the switch-rails in position for the main track.

The switch can be trailed through from the turnout while set for the main track, as the flange of the inner wheel forces the switch open against the action of the spring. The spring immediately closes the switch after the passage of the wheels. The switch must be thrown when it is necessary to enter the turnout from the main track. In this position it can be trailed through from the main track. Spring-switches should not be used in any track carrying fast and heavy traffic. They are used frequently on industrial railways and occasionally in electric railway track.

When the main rails carry electric circuits the head-rod, tie-bars, and all connecting and operating parts of the two switch-rails must be insulated in such a way that there is no leakage of current between rails.

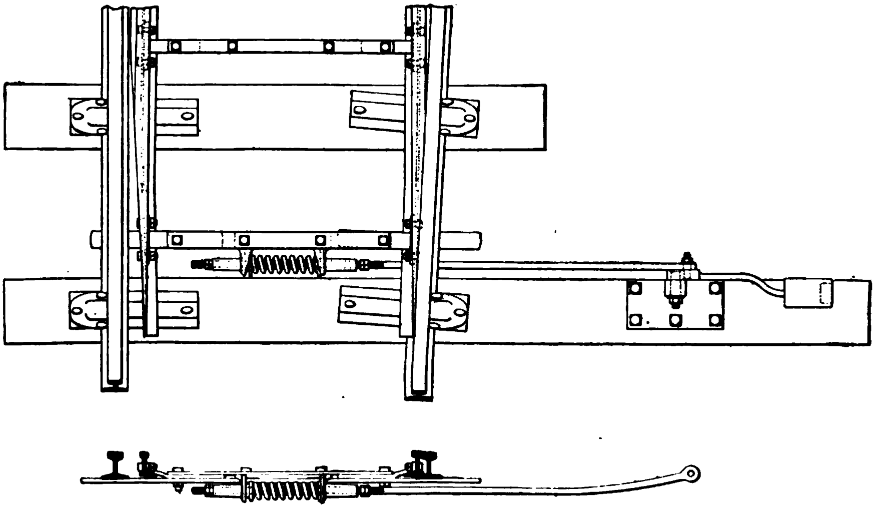


FIG. 173.—Spring-switch.

216. Switches Allowing Continuous Main Rails.—Several switches have been designed which maintain the continuity of both main-track rails through the switch. This is accomplished by lifting the inner wheel over the main rail. The two best-known switches of this type are the Wharton and the MacPherson. The principle in each is really the same. A rail having an inclined top is placed outside the main rail on the inside of the turnout. When set for the turnout the inclined rail engages the tread of a wheel passing over it, and in running up the ramp the wheel is raised about 1½ in., or enough for the wheel-flange to clear the top of the main rail. The opposite wheel is then engaged by a switch-rail which guides the wheel into the turnout. The Baltimore and Ohio Railroad uses Wharton switches at high-speed points for facing point-switches leading from the outside of curves to sidings infrequently used. A derailing switch of the Wharton type is used on the Grand Trunk Railway.

217. Frogs.—A frog is a device used at the intersection of two rails to permit the flanges of the wheels riding on one rail to cross the other rail. According to the purpose for which used, frogs may be classified as turnout frogs and crossing frogs. On a basis of operation, frogs may be classified as rigid, spring-rail, movable point, and special. The theoretical point of the frog is at the intersection of the gage lines of the two rails. The actual point is made blunt and is several inches from the theoretical point. The width of point varies from ¼ to ⅝ in., ½ in. commonly being used. The principal parts of a frog are shown in Fig. 174.

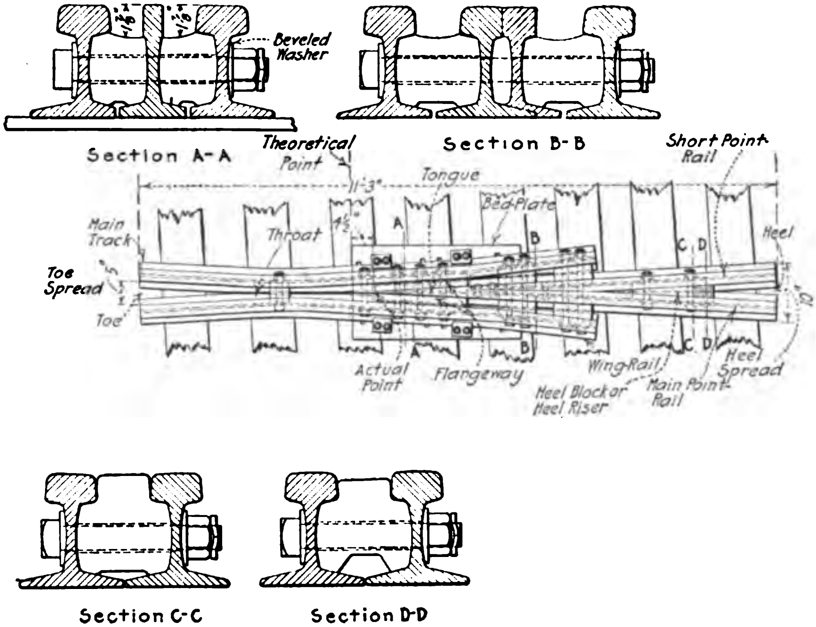


FIG. 174.—Principal parts of a frog.

Frogs are designated by angles and by numbers. The frog angle is the angle between gage lines of the tongue. The frog number is the ratio of length divided by the spread between gage lines at the heel. Unfortunately this definition can be interpreted in two ways. The length can be measured either along the gage line or along a line bisecting the angle. The former method is the more practical for field purposes, but the American Railway Engineering Association recommends the latter method. Referring to Fig. 175,

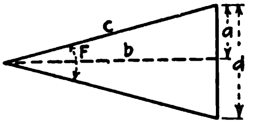


FIG. 175.—Frog number.

Let F = frog angle,

and N = frog number.

If the length is measured along the gage line,

$$N = \frac{c}{d} = \frac{1}{2}\frac{c}{a} = \frac{1}{2}\operatorname{cosec}\frac{1}{2}F \qquad (217a)$$

If the length is measured along the bisector,

$$N = \frac{b}{d} = \frac{1}{2}\frac{b}{a} = \frac{1}{2}\cot\frac{1}{2}F \qquad (217b)$$

By the first method $\sin\frac{1}{2}F = \frac{a}{c}$, and by the second method $\tan\frac{1}{2}F = \frac{a}{b}$. If the number of a frog found by one method is the same as the number of another frog found by the other method, the angles of the two frogs will not be the same. The two methods give about the same results above a No. 12 frog, the angles found according to equation 217*a* being slightly the larger for all numbers. Table 18 shows the difference in the two methods for frogs from No. 4 to No. 12.

TABLE 18.—FROG ANGLES FOR NO. 4 TO NO. 12 FROGS

Frog No.	$\frac{a}{b} = \tan\frac{1}{2}F$	Angle $\frac{a}{c} = \sin\frac{1}{2}F$ difference
4	14° 15′ 00″	5′ 41″.436
5	11 25 16	3 26.024
6	9 31 39	2 48.378
7	8 10 16	1 15.520
8	7 09 10	0 49.916
9	6 21 35	0 35.121
10	5 43 29	0 26.084
11	5 12 18	0 19.809
12	4 16 19	0 14.714

The number of an existing frog can be found in several ways, the most accurate of which is to measure the total length of frog from toe to heel and divide this by the sum of the toe and heel spreads, all dimensions being measured in the same units. A second method is to measure the distance in feet from the theoretical point to a point where the spread is just 1 ft. This distance in feet is the number of the frog. The frog number defines the angle the outer turnout rail makes with the inner main-track rail at the point of intersection. A frog of a given number has the same angle whether used on a tangent or on a curve, or in a standard-, wide-, or narrow-gage track. However, the turnout curve will differ greatly for these conditions. Also, all frogs of the same number do not have the same length, so that the length of lead and degree of turnout curve may differ under identical conditions of gage, curvature, and frog number. It is really the distance from the toe to the theoretical point that is important. The length of the switch-rail and the switch angle also have an effect upon the length of lead and degree of turnout curve. The Southern

Railway uses the following rules for dimensioning frogs: (1) The length of any frog in feet is one and one-half times the frog number. (2) The number of any frog is represented by the distance in feet from the theoretical point to heel. (3) The distance from theoretical point to actual point, in inches, is one-half the number of the frog.

The point of a frog receives very hard usage and in time is battered and often broken, even if composed of the hardest and toughest metal. Also the blows received by each wing-rail at the knuckles—near the throat of the frog—are severe. Since the tongue of a frog does not taper to a long narrow point like a switch-point, manganese steel can be used.

218. Rigid Frogs.—The necessary flangeway through a rigid frog makes a break in both the turnout and main-track rail. Rigid frogs are of the following types: solid, rail-bound, and built-up. A solid frog is one consisting of a single hollow casting of manganese steel or other hard metal. A rail-bound frog, also called an insert or hard-center frog, is built up as described below for the built-up frog, but has a hollow casting of hard metal set in to form the tongue and the knuckles of the wing-rails. A rail-bound or hard-center frog is shown in Fig. 176.

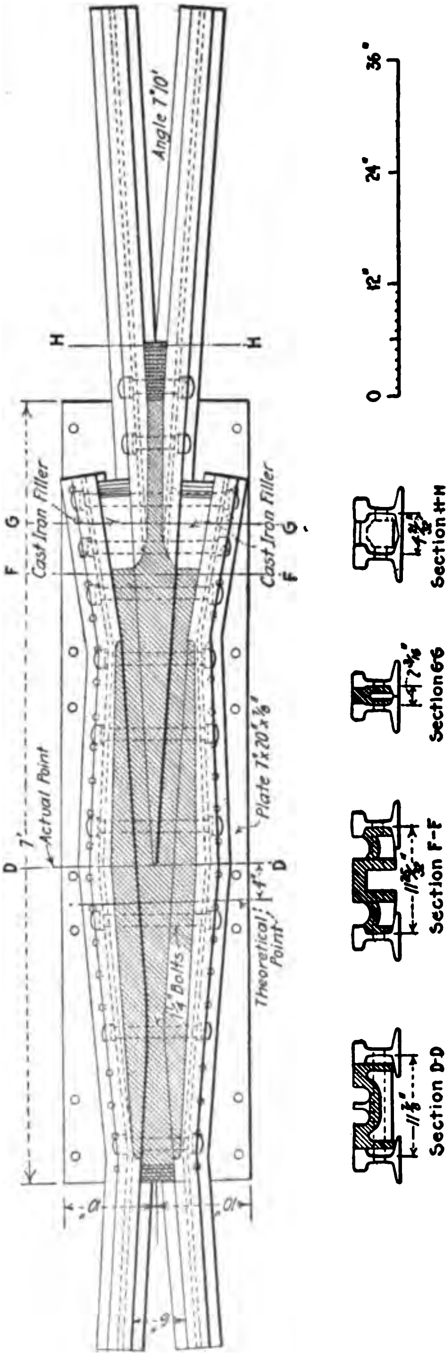


Fig. 176.—Number 8 rail-bound frog for 100-lb. rail.

Hard-center frogs should be used at all points where both tracks carry heavy traffic at high speeds, as at the ends of double track. Built-up frogs are built up of pieces of rails bent and planed to shape, properly spaced by filler blocks and held together either by bolts or clamps. The parts of a bolted rigid frog are frequently bolted to a bed-plate which rests on and is spiked to the ties. The frogs shown in Figs. 174 and 176 are of the bolted type, both also being bolted to bed-plates. A No. 7 clamped rigid frog for a 100-lb. rail is shown in Fig. 177. The clamps project between the ties and prevent the use of a bed-plate. For several years the Southern Railway has had in service a number of bolted rigid frogs which have rolled manganese-steel wing-rails and open-hearth steel point-rails. Rigid frogs made from ordinary Bessemer or open-hearth rails should be used only in tracks of light traffic.

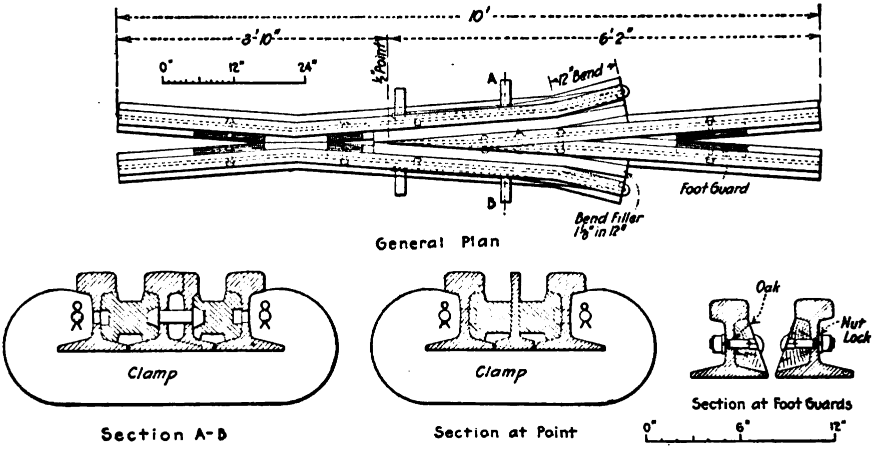


FIG. 177.—Number 7 clamped rigid frog for 100-lb. rail.

219. Spring-rail Frogs.—Spring-rail frogs are designed to provide an unbroken riding surface for one or both rails, hence are either single or double. They are used in main tracks at high speed points when the turnout is used at comparatively low speeds, and in general, at points where the traffic on one track is much heavier than on the other. They should not be used at any point where high speed is maintained through the spring-rail. Usually most movements are on one track and the single-rail type is used. The distinctive feature of a spring-rail frog is the hinged wing-rail on the turnout side, which connects with the main rail at the toe. The hinge is near the toe. The filler block is omitted between this wing-rail and the tongue, and a stiff spring holds the wing-rail against the tongue, providing no flangeway for the turnout rail and maintaining a continuous surface for the main rail. The wing-rail is pushed open by the flange of a wheel rolling in either direction on the turnout rail, thus providing the flangeway only when needed. After the passage of the wheel the spring returns the wing-rail to its normal position against the tongue. Both wing-rails of a double spring-rail frog are movable and normally lie against the tongue, so that no flangeway is provided for either track.

The horizontal and vertical movement of the wing-rail is controlled by stops fastened to the ties and by horizontal plunger rods fastened to the wing-rail and sliding in hold-down stirrups fastened to the ties. The hold-down should allow not more than ⅛ in. vertical play. The stops should be so placed as to allow the spring-rail to open 1⅞ in. opposite the point of frog. Two general types of springs are in use. The type more commonly used is shown at (*A*), Fig. 178, and consists of two connected springs, one on the outside of each wing-rail. Both springs are compressed when the wing-rail opens. The other type, shown at (*B*), has one long coiled spring and is placed outside the spring-rail. The rela-

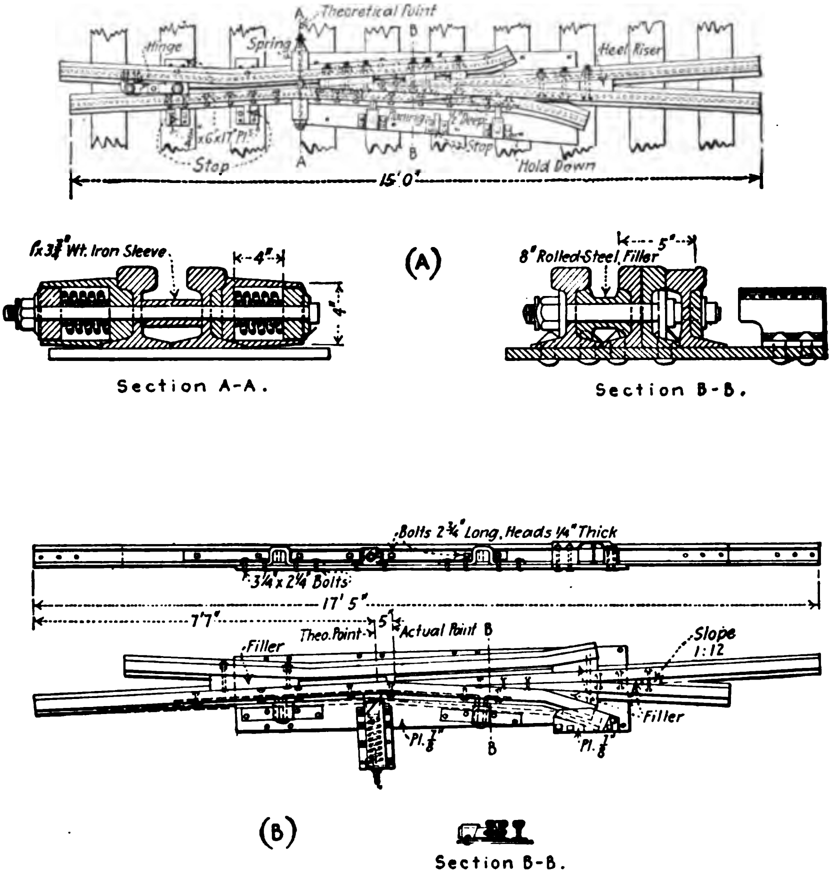


FIG. 178.—Number 10 spring-rail frogs.

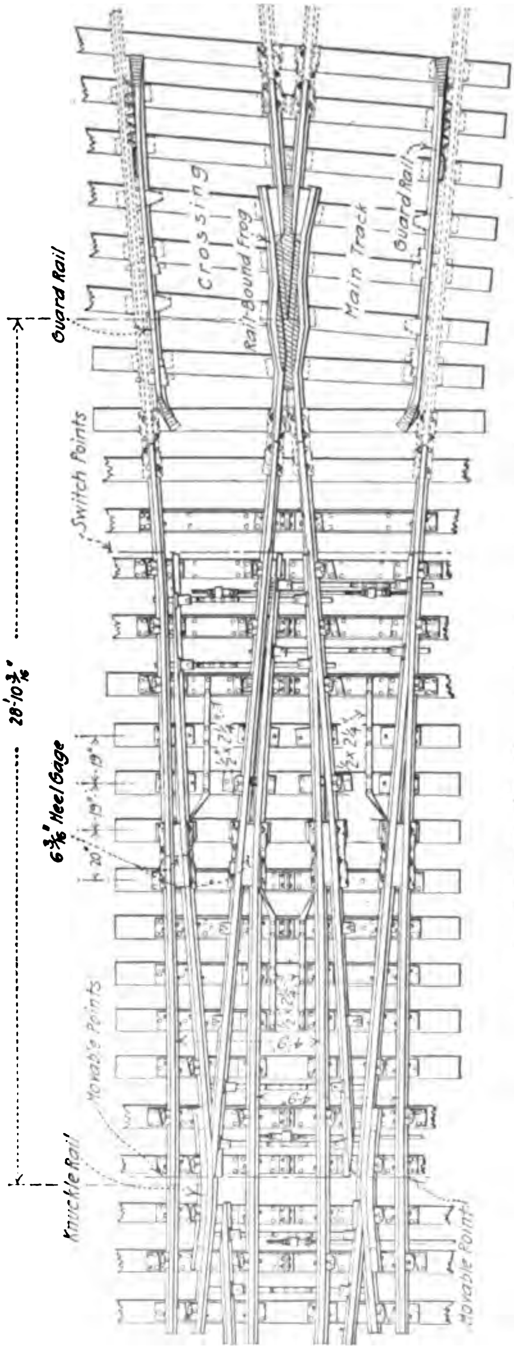


FIG. 179.—Double slip-switch and movable-point frogs.

tive positions of the hinge, spring, point of frog, and end of wing-rail determine the resistance to opening of the wing-rail. The spring is usually placed about opposite the theoretical point, but in some designs it is placed opposite the tongue, several inches back of the actual point. The standard No. 10 18-ft. spring-rail frog of the Pittsburgh and Lake Erie Railroad has a spring of each type; there is a double spring 2 ft. 9 in. from the actual point, toward the toe, and a single spring about 21 in. from the actual point, toward the heel.

220. Movable-point and Special Frogs.—A movable-point frog consists of two pointed movable rails facing in opposite directions, with the points separated by about 6 in. When either movable rail is in contact with the knuckle-rail the other is open to provide a flangeway. In this way both rails are continuous through the frog. Movable-point frogs are used principally at crossings, where they can be used in pairs, the same mechanism operating both frogs. They are best adapted to tracks where the traffic is slow and heavy on both tracks, as on ladder tracks, etc., but should not be used in main tracks. When used as center frogs at slip-switches the switches and movable points can be operated by one mechanism. They are usually operated as part of an interlocking plant, but also can be operated by hand. Figure 179 shows the arrangement of movable-point frogs in a double slip-switch.

Several special frogs for maintaining the continuity of the rails have been tried, particularly at crossings. One type has revolving parts which in one position provide a flangeway, and in another position close the flangeway and make the rails continuous. Another type consists of four rails forming the closing numbers of the intersection at a crossing. The four rails move vertically in pairs and the flangeway is provided by the two rails not to be used dropping vertically far enough to clear the wheel-flanges.

221. Crossings.—The design of a crossing depends on the angle of the crossing. For angles from about 30° or 32° to 90° the entire crossing or diamond should be one rigid piece, either a solid casting or built up of pieces of rails bolted. Bolted crossings are ordinarily of the two-rail or three-rail type, that is, either two or three parallel rails are bolted to form each rail. A bolted crossing is shown at (*A*), Fig. 180. This is a combination two- and three-rail crossing and is used at the crossing of a heavy-traffic line with a light-traffic line, as at the crossing of a steam-railway and electric railway. When the crossing angle is less than about 30° and 32° a crossing similar to that shown at (*B*) is less expensive. Two types of frogs are used in this kind of a crossing. The end frogs, *Y*, are the ordinary type of rigid frog. The center frogs, *X*, are double-pointed. The ends of the wing-rails of an ordinary or single-pointed frog connect at the toe to the track-rails. Besides the two points, a double-pointed frog has a knuckle-rail and a wing-rail. The latter is independent of either track-rail and acts merely as a guard-rail. Manganese is used extensively in crossing-construction, the crossing either being a solid casting or having manganese points and knuckles.

222. Slip-switches.—A slip-switch is a combination of one or two pairs of turnouts and a crossing, each pair of turnouts having a common curved lead- and stock-rail, and the end frogs of the crossing serve as frogs for the turnouts. The entire turnout lies within the limits of the end frogs of the crossing. A slip-switch is either single or double, according to whether there are one or two pairs of turnouts. Figure 179 shows a No. 6 double slip-switch. The complete arrangement is symmetrical about the center frogs, which in the figure have movable points. The number of a slip-switch is the same as that of the crossing-frogs. Slip-switches may be used at any crossing where the angle of intersection is not greater than that of a No. 6 frog. It is possible to use them with larger angles but the turnout curves will be very short and sharp and are difficult to operate and maintain. Slip-switches are used to give greater flexibility of movement in yards and at entrances to passenger-terminals. In some cases their pressure indicates an inadequate arrangement of tracks into which the slip-switch was introduced as a last resort.

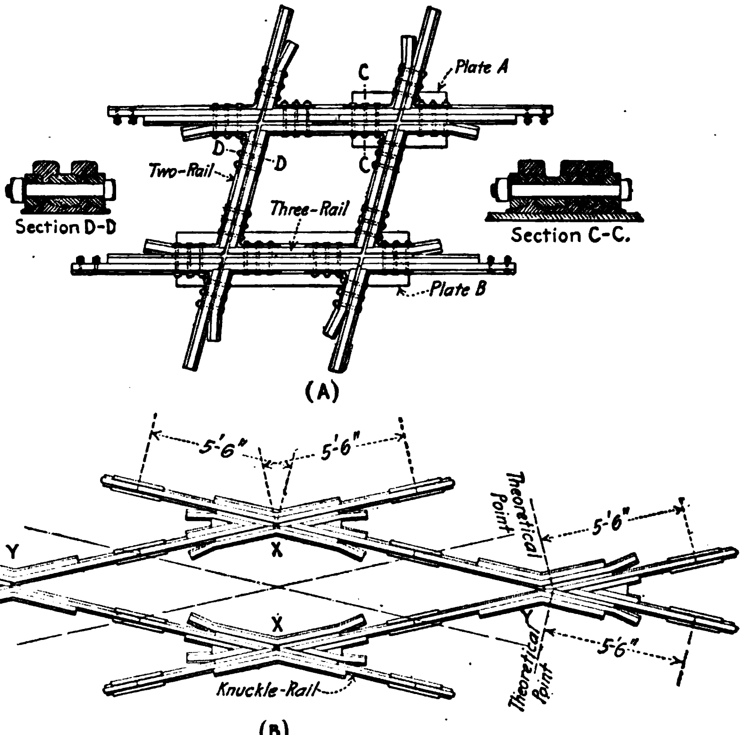


FIG. 180.—Crossings.

223. Guard-rails.—A guard-rail must be placed on the outer main-track rail and inner turnout rail, opposite all turnout frogs, as shown opposite the end frog in Fig. 179. The two guard-rails at each frog are absolutely necessary to prevent wheel-flanges from fouling the frog point when moving over it in a facing direction. This is the sole function of the frog guard-rail. The length of the guard-rail is from 6 to 18 ft. The ends are given a flare to prevent the wheel-flanges from striking the end of the guard-rail if the track is out of gage or line. The shorter lengths, if rigidly held in place, are satisfactory, and are somewhat

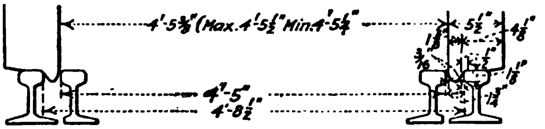
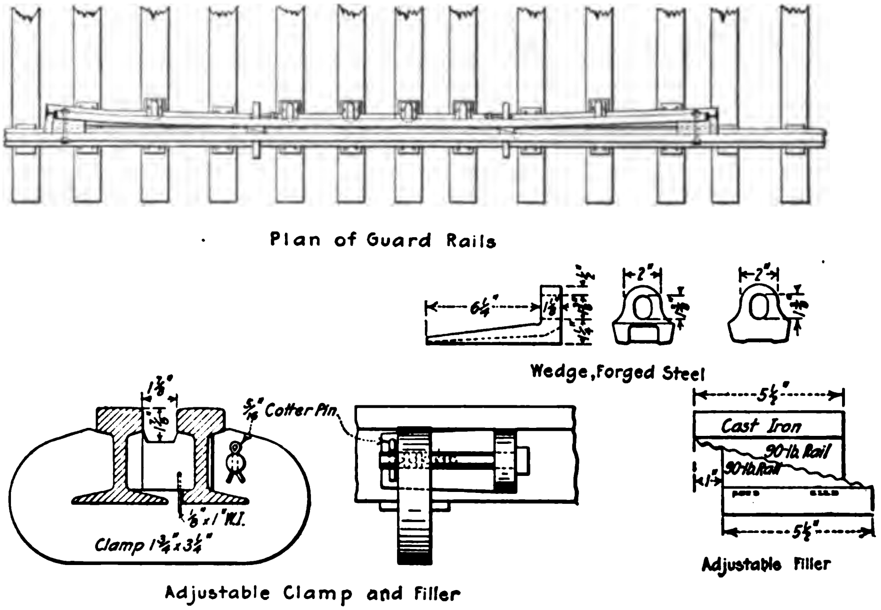


FIG. 181.—Standard gage of guard-rails; Master Car Builders' Association.

cheaper. The standard gage and wheel dimensions of the Master Car Builders' Association are shown in Fig. 181. The angle of flare of the ends should be small to reduce the shock of blows received from wheel-flanges. The maximum flare at the ends should be not less than 3½ in., or twice the width of the standard flangeway, which is 1¾ in. for a gage of 4 ft. 8½ in. When the gage is increased on curves the flangeway is increased, as the gage of guard-rails must be constant at 4 ft. 5 in. This dimension should never vary as it is used as the basis for the clearance and distance between wheel-flanges. The angle of flare should be about 4° 30′. The usual practice in the past has been to use filler blocks between the guard-rail and main rail, bolt the two rails through these, and place several rail-braces outside the guard-rail to prevent its gage from decreasing. This method does not prevent the gage from increasing, and wear of guard-rails may cause the gage to decrease. A metal or wooden foot-guard should be provided at each end of every guard-rail and in several States is required by law. A guard-rail held to the main rail by one or more rigid clamps, Fig. 182, is now used extensively and is very satisfactory. The flangeway is maintained by two interlocking wedges driven in opposite directions between the main rail and guard-rail, at the jaws of the clamp, and a wedge driven between the clamp and the outer side of the main rail. The latter wedge is held in place by cotter pins. The usual guard-rail consists of a piece of rail cut to the proper length


Plan of Guard Rails

Wedge, Forged Steel

Adjustable Clamp and Filler

Adjustable Filler

FIG. 182.—Clamp guard-rail.

and having the ends bent to give the proper flare. Recently several railways have installed guard-rails consisting of one-piece, hollow, manganese castings. These are quite expensive but the short time they have been in service indicates that their life will be considerably longer than that of the ordinary guard-rail made from a T rail.

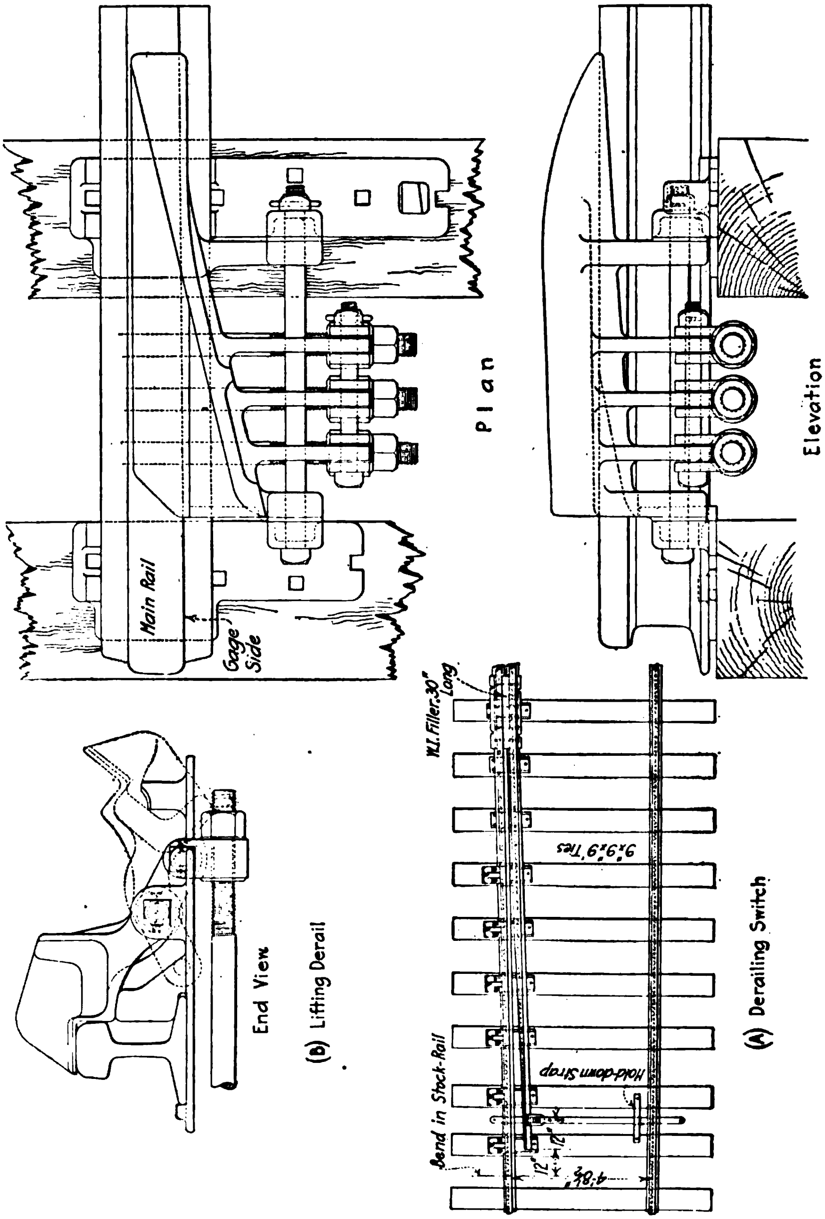


Fig. 183.—Derails.

224. Derailing Switches and Derails.—A derailing switch or derail is used on sidings to prevent cars or trains from fouling the main track; and on main track at all interlocked switches, drawbridges, crossings, etc., and occasionally at such places when not interlocked, to throw trains which have run past stop- or danger-signals, from the track and prevent serious accidents. In all cases, except where the brakes of a standing car slip and allow the car to move, derails are used as a check on the engineman or trainmen in properly interpreting signals. Derails are of four general types, namely, split-switch, continuous-rail switch, stub-switch, and lifting. The two commonest forms are the split-switch and lifting derail. These are shown at (*A*) and (*B*), Fig. 183. The split derailing switch, (*A*), consists of the inner switch-rail of a split-switch. When the switch is closed the rails are continuous; when open, the switch-rail acts as a guard-rail in engaging the flange of one wheel and deflects that wheel to one side, pulling the opposite wheel from the rail, thus derailing the train. A few railways use a standard switch and connect the switch to a short length of track at the side of the main track. This prevents damage to the track and rolling-stock but does not always serve as a warning to the engineman. A derailing switch of the Wharton type is used by several railways. Only derails of the split-switch or continuous-rail type should be used in main track. On main track an outer guard-rail on the side of the derail or an inner guard-rail opposite the derail is often placed beyond the derail to keep a derailed train out of the ditch. The lifting type, shown at (*B*), is used on sidings and in yards. It consists of a heavy hinged casting which lies on top of the rail when set to derail and lifts backward about 180° clear of the rail when set for a clear track. The top of the derail is a diagonal inclined plane, starting on the inside and terminating on the outside of the rail. When in position on the rail the flange of a wheel is engaged and lifted over the rail by the inclined plane, and the wheel is dropped upon the ties on the outside of the rail. The opposite wheel is of course pulled off the rail.

225. Turnouts.—A turnout is a track arrangement by which a train may pass from one track to another. It begins at the switch and ends with the last switch-tie, or with the frog when long ties are not used. It consists of the following five parts, with their fastenings, connections and operating devices: (1) Switch. (2) Lead-rails. (3) Frog. (4) Guard-rails. (5) Switch-ties. There is no problem in railway location or maintenance for which so many solutions have been proposed as for computing and locating in the field the various parts of a turnout. The following solution is recommended by the American Railway Engineering Association.

In Fig. 184

1. Let $G = PB$ = gage of track,
2. N = frog number,
3. F = frog angle,
4. $W = PK$ = length of wing-rail,
5. $S = AC$ = length of switch-rail,
6. $H = CZ$ = heel distance,
7. u = angle COE_1 = angle subtended by chord of lead curve from heel of switch to any point on the gage side of the outer rail of lead curve,
8. t = thickness of frog point,
9. t' = thickness of switch point,

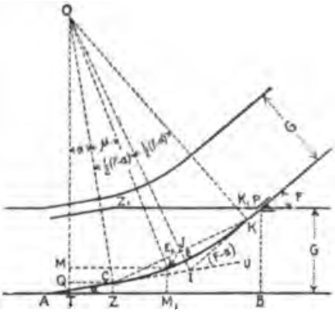


FIG. 184.—Theory of the turnout.

10. P = theoretical point of frog,
11. K = toe of frog,
12. A = point of switch-rail,
13. B = foot of perpendicular from actual point of frog upon gage side of opposite main-track rail,
14. C = heel of switch-rail,
15. Z = foot of perpendicular from gage side of switch-rail at heel upon gage side of main-track rail,
16. O = center of lead curve,
17. a = angle CAZ = switch angle,
18. $L = AB$ = lead distance measured along center line of main track from actual point of switch to actual point of frog,
19. R = radius of center line of lead curve,
20. D = degree of lead curve,
21. $U = CE_1\ EK$ = arc of outer rail of lead curve,
22. $V = Z_1K_1$ = length of straight rail in lead,
23. $Y = E_1M_1$ = perpendicular offset from any point on the curved lead-rail to the main-track rail.
24. $X = M_1A$ = distance from foot of such offset to point of switch-rail.

Items 1 to 9 inclusive are known. Items 10 to 16 inclusive relate to the construction of the figure. Items 17 to 24 inclusive are to be found.

$$\sin a = \frac{CZ - t'}{AC} = \frac{H - t'}{S}$$

$$a = \sin^{-1}\left(\frac{H - t'}{S}\right) \qquad (225a)$$

If c = distance measured along gage line of main-track rail from theoretical to actual point of frog, $c = Nt$. The sum of the projections of AC, CK, and KP upon PB is equal to $PB - t'$, or,

$$G - t' = S \sin a + CK \sin \tfrac{1}{2}(F + a) + W \sin F,$$

$$CK = \frac{(G - t') - (W \sin F + S \sin a)}{\sin \frac{1}{2}(F + a)} \qquad (225b)$$

Projecting the same lines upon AB and adding the value of c,

$$AB = L = S \cos a + CK \cos \tfrac{1}{2}(F + a) + W \cos F + Nt \qquad (225c)$$

Substituting in Eq. c the value of CK found in Eq. b,

$$L = S \cos a + \frac{[(G - t') - (W \sin F + S \sin a)] \cos \frac{1}{2}(F + a)}{\sin \frac{1}{2}(F + a)} + W \cos F + Nt$$

Reducing,

$$L = (S - W)\frac{\sin \frac{1}{2}(F - a)}{\sin \frac{1}{2}(F + a)} + (G - t') \cot \tfrac{1}{2}(F + a) + Nt \qquad (225d)$$

$$OK = \frac{JK}{\sin KOJ} = \frac{CK}{2 \sin \frac{1}{2}(F - a)}$$

Substituting the value of CK from Eq. b, and reducing,

$$OK = \frac{(G - t') - W \sin F - S \sin a}{2 \sin \frac{1}{2}(F - a) \sin \frac{1}{2}(F + a)} \qquad (225e)$$

$$S \sin a = H - t', \text{ and } R = OK - \tfrac{1}{2}G$$

Therefore,

$$R = \frac{G - H - W \sin F}{2 \sin \frac{1}{2}(F - a) \sin \frac{1}{2}(F + a)} - \frac{G}{2} \qquad (225f)$$

$$= \frac{G - H - W \sin F}{\cos a - \cos F} - \frac{G}{2} \qquad (225g)$$

$$\sin \tfrac{1}{2}D = \frac{50}{R}, \quad D = 2 \sin^{-1}\left(\frac{50}{R}\right) \qquad (225h)$$

$$U = 2\pi\left(R + \frac{G}{2}\right)\frac{(F - a)}{360}$$

$$= 0.017453\left(R + \frac{G}{2}\right)(F - a) \qquad (225i)$$

where $(F - a)$ is in degrees and decimals.

$$V = L - (W + Nt + S) \qquad (225j)$$

$$Y = E_1M_1 = MT = OQ - OM + CZ$$

$$OQ = \left(R + \frac{G}{2}\right)\cos a, \quad OM = \left(R + \frac{G}{2}\right)\cos (a + u)$$

$$Y = H + \left(R + \frac{G}{2}\right) \cos a - \left(R + \frac{G}{2}\right) \cos (a + u) \qquad (225k)$$

$$X = M_1A = AZ - QC + ME_1$$

$$AZ = S \cos a, \ QC = \left(R + \frac{G}{2}\right) \sin a, \ ME_1 = \left(R + \frac{G}{2}\right) \sin (a + u)$$

$S \cos a = S$, very nearly. The error in this assumption is only 0.01 ft. for an 11-ft. switch-rail, ¼-in. thickness of switch-point, and 6¼-in. spread at heel.

Therefore,

$$X = S - \left(R + \frac{G}{2}\right) \sin a + \left(R + \frac{G}{2}\right) \sin (a + u) \qquad (225l)$$

In laying out the turnout, points on the curved lead-rail, corresponding to $u = \frac{1}{4}(F - a)$, $u = \frac{1}{2}(F - a)$, and $u = \frac{3}{4}(F - a)$, should be obtained.

The lengths of wing-rails KP and K_1P are not always equal. If such is the case the actual value of K_1P must be substituted for W in Eq. *j*. The values of V and U found by these formulas may frequently require the use of rails of special lengths. It is often desirable to use a certain number of rails of known length in the leads. By assuming a greater value of W or S than the actual value, which would necessitate the introduction of a short tangent at the heel of the switch or at the toe of the frog, the position of the point P can be shifted nearer to or farther away from Z_1. Shifting the point P will increase the degree of curvature of the turnout curve.

226. The Design of Turnouts.—The two important things to be determined in designing a turnout are (1) the number of the frog best adapted to the requirements of service and space available, and (2) the length of switch to be used. Experience has shown that for satisfactory operating results the ratio of switch angle to frog angle should be about 1 to 4 and not greater than 1 to 3½. Increasing the length of a switch used with a given length of frog increases the degree of the turnout curve and, though lessening the change in direction at the switch point, may render the turnout more difficult to operate. Turnouts may be divided into the following four general classes, according to their use: (1) turnouts from sidings; (2) turnouts from main tracks to sidings; (3) main-track turnouts operated at medium speed; (4) main-track turnouts operated at high speed.[1] Turnouts of the first class are used only where the movements over them are for switching purposes, and cannot be used for road-engines. They include all frogs less than No. 6, and are usually used with a 10-ft. switch, which should be the minimum length for any switch-rail. The second class includes frogs from No. 6 to about No. 9. These are used with switches from 10 to 18 ft. in length. Numbers 10 to 14 are used for the third class and the length of switch varies from 15 to 24 ft. The fourth class includes numbers 15 to 24, which are used with 15- to 33-ft. switch-rails. The American Railway Engineering Association recommends the use of 16½-ft. switch-points for all new work for frogs over No. 6 up to and including No. 10; 22-ft. points for frogs over No. 10 up to and including No. 14; 33-ft. points for frogs over No. 14; and 11-ft. points for No. 6 and under.

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[1] The Essential Elements in the Design of Switch Connections, by W. F. Rench, Railway Age Gazette, Feb. 19, 1915.

To avoid carrying a large stock of frogs of different numbers, each railway should adopt as standard one or two frogs of each class which will best meet the requirements of that railway, and these should be used in all new work, so as ultimately to eliminate all frogs of other numbers. Numbers 8, 11 and 16 respectively are recommended by the American Railway Engineering Association as meeting all general requirements for yards, main-track switches, and junctions.

227. Locating Turnouts.—Turnouts can be located by laying out the center line or by setting points for the curved rail of the turnout, or by both. A transit instrument should be used when possible, but a simple turnout can be located accurately by tape measurements alone. Table 19 gives all necessary data for laying out the center lines and locating the required points for turnouts, crossovers, and ladders for frogs from No. 4 to No. 20, and for lengths of switch-rail from 11 ft. to 30 ft. The values were calculated for a width of frog-point of ½ in. and a width of switch-point of 9/32 in. The spread at the heel of the switch is given in column 6. A width of 13 ft. between track centers was used. For any other spacing column 11 gives the corrections to be used.

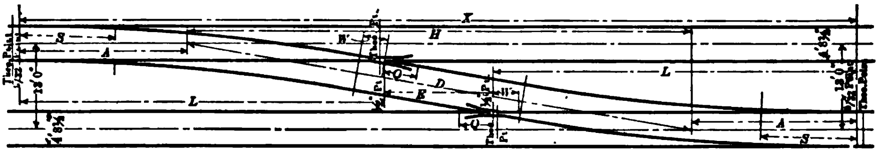
A double crossover or "scissors" consists of two crossovers between parallel tracks. The crossovers face in opposite directions and are symmetrical about a line midway between centers of the parallel tracks, the theoretical points of the end frogs of the crossing being on this line.

A simple turnout can be located by offsets or rectangular coordinates with either the actual point of frog or actual point of switch as the origin, the distances being computed by Eqs. 225*k* and 225*l*. The offsets are measured from and perpendicular to the gage of the outer main-track rail to the gage of the outer turnout rail. These offsets are also very useful in maintaining the gage and alignment of the turnout, as the alignment can be checked in a few minutes by measuring six or eight distances. Table 20 gives data for locating a turnout by offsets, the offsets being taken at the one-quarter, one-half, and three-quarters points from heel of switch to actual point of frog.

228. Switch-ties.—Long ties generally are used at turnouts so that the rails of the two tracks rest on the same ties, as shown in Fig. 185. The arrangement for a turnout is shown at (*A*) and that for a crossover is shown at (*B*). Both are No. 8. The figures at the upper ends of the ties are the spacings in inches from center to center of ties. The figure at the lower end of each tie is the length of the tie in feet. The turnout requires 54 ties, which, for 7- by 9-in. ties, contain 3360 ft. board-measure. The crossover requires 92 ties, containing 6255 ft. board-measure.

The maximum length of switch-ties is 17 ft. The length of head-blocks ranges from 12 to 20 ft. The shorter lengths are used for low switch-stands and the longer lengths for high switch-stands. If the turn-

Table 19.—Data for Laying Out Turnouts, Crossovers, and Ladders



1	2	3	4	5	6	7	8	9	10
Frog No.	Length of frog	Toe to ½-in. point	½-in. point to heel	Length of switch	Spread at heel of switch	Frog angle			Distance between switch points
	W & Q	W	Q	S			E	H	X
4	8′ 0″	3′ 0″	5′ 0″	11′ 0″	5½″	14° 15′ 00″	13.19′	51.19′	93.19′
4½	8′ 0″	3′ 0″	5′ 0″	11′ 0″	5½″	12° 40′ 49″	15.03′	57.78′	98.03′
5	8′ 0″	3′ 0″	5′ 0″	11′ 0″	5½″	11° 25′ 16″	16.85′	64.35′	106.85′
6	8′ 0″	3′ 0″	5′ 0″	16′ 6″	6½″	9° 31′ 39″	20.46′	77.46′	134.46′
6	8′ 0″	3′ 0″	5′ 0″	15′ 0″	6½″	9° 31′ 39″	20.46′	77.46′	128.46′
6	8′ 0″	3′ 0″	5′ 0″	13′ 0″	5½″	9° 31′ 39″	20.46′	77.46′	128.46′
7	15, 0″	6′ 6″	8′ 6″	16′ 6″	6½″	8° 10′ 16″	24.04′	90.54′	145.04′
7	15′ 0″	6′ 6″	8′ 6″	15′ 0 ′	6½″	8° 10′ 16″	24.04′	90.54′	145.04′
7	8′ 0″	3′ 0″	5′ 0″	15′ 0″	6½″	8° 10′ 16″	24.04′	90.54′	145.04′
7	8′ 0″	3′ 0″	5′ 0″	13′ 0″	5½″	8° 10′ 16″	24.04′	90.54′	145.04′
8	10′ 0″	4′ 0″	6′ 0″	16′ 6″	6½″	7° 09′ 10″	27.59′	103.59′	161.59′
8	15′ 0″	6′ 6″	8′ 6″	16′ 6″	6½″	7° 09′ 10″	27.59′	103.59′	161.59′
8	15′ 0″	6′ 6″	8′ 6″	15′ 0″	6½″	7° 09′ 10″	27.59′	103.59′	154.59′
8	15′ 0″	6′ 6″	8′ 6″	13′ 0″	5½″	7° 09′ 10″	27.59′	103.59′	154.59′
10	15′ 0″	6′ 6″	8′ 6″	16′ 6″	6½″	5° 43′ 29″	34.68′	129.68′	188.68′
10	15′ 0″	6′ 6″	8′ 6″	15′ 0″	6½″	5° 43′ 29″	34.68′	129.68′	183.68′
12	18′ 0″	8′ 0″	10′ 0″	24′ 0″	6½″	4° 46′ 19″	41.73′	155.73′	239.73′
12	18′ 0″	8′ 0″	10′ 0″	16′ 6″	6½″	4° 46′ 19″	41.73′	155.73′	213.73′
15	20′ 0″	8′ 0″	12′ 0″	24′ 0″	6½″	3° 49′ 06″	52.28′	194.78′	282.28′
15	20′ 0″	8′ 0″	12′ 0″	16′ 6″	6½″	3° 49′ 06″	52.28′	194.78′	250.28′
16	20′ 0″	8′ 0″	12′ 0″	24′ 0″	6½″	3° 34′ 47″	55.80′	207.80′	295.80′
20	27′ 0″	9′ 6″	17′ 6″	• 30′ 0″	6½″	2° 51′ 51″	69.84′	259.84′	368.84′

All distances are calculated to the ½-in. frog point and to the 9/32-in. switch point and for 13 ft. center column eleven, and add to or subtract from D the quantity in column eighteen for each foot variation.

out is to a track parallel to the main track, the ties in the turnout beyond the switch-ties are maintained parallel to the switch-ties. Otherwise the ties beyond the switch-ties are laid perpendicular to the rails of the turnout. When long switch-ties are not available a set of standard ties is placed under each track, the inner ends dovetailing. The length of switch-ties increases by steps of 6 in. or 1 ft. from the switch to the end of the turnout. The minimum projection of a tie of any group should be the standard distance from gage line to end of tie. The ties are lined from the outer main-track rail. The common practice is to allow the ends of one group to project beyond the next group, on the turnout side. However, a few railways go to the trouble of sawing the inner ends of all ties parallel to the inner turnout rail, maintaining the standard distance from gage line to each end of each switch-tie. This allows a uniform ballast shoulder and has a neater appearance.

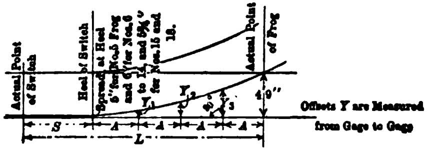
Table 19.—Data for Laying Out Turnouts, Crossovers, and Ladders.—*Continued*

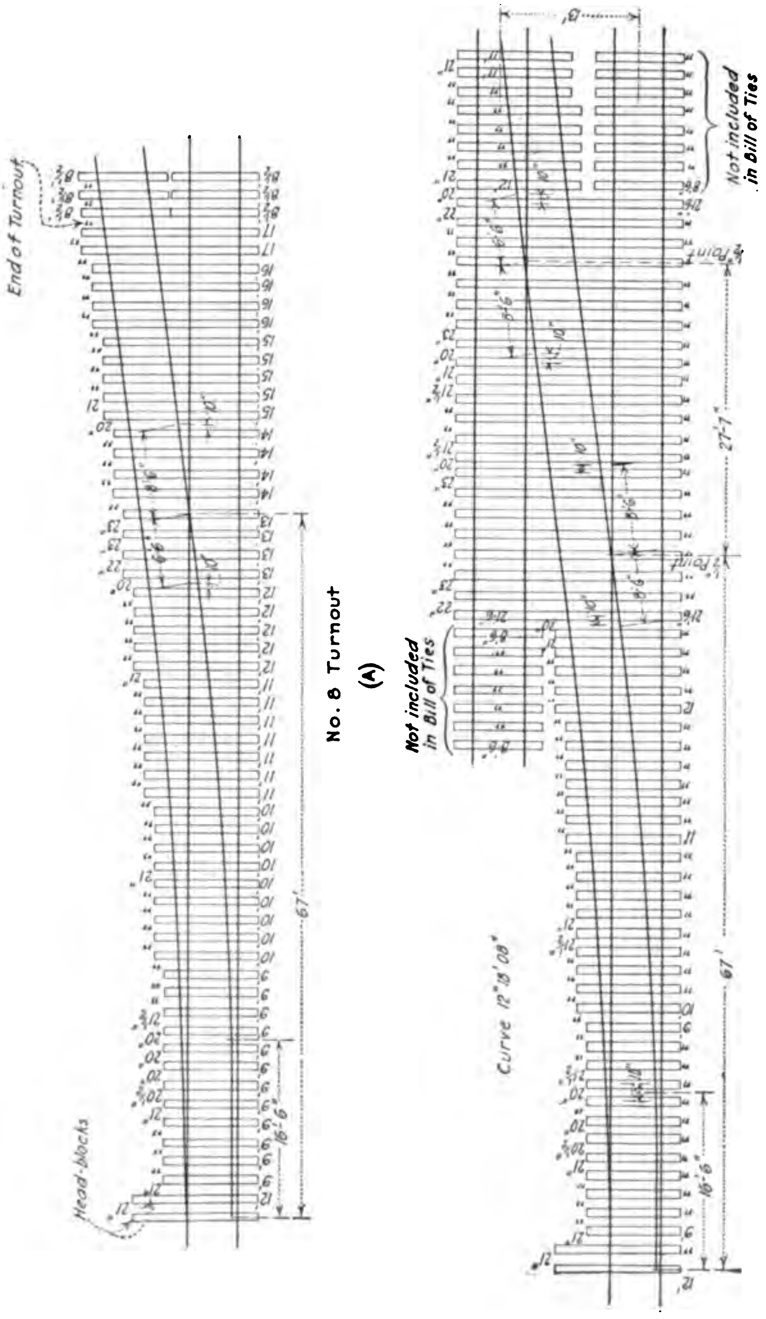
1	11	12	13	14	15	16	17	18	19
Frog No.	Correction for E, H, & X per foot	Degree of curve of outer rail	Lead on center line	Adjusted lead	Switch angle	9/32-in. P. S. to theo. P. S.	Distance c. to c. on ladder	Correction for D, per foot	Exact calculated lead
			A	L			D		
4	3.94′	49° 55′ 33″	21′.00″	40′ 0″	2° 15′ 51″	7⅛″	52.81′	4.06′	38.39′
4½	4.44′	37° 55′ 14″	20.13′	41′ 6″	2° 15′ 51″	7⅛″	59.22′	4.56′	41.62′
5	4.95′	29° 48′ 29	21.25′	·45′ 0″	2° 15′ 51″	7⅛″	65.65′	5.05′	44.75′
6	5.96′	20° 38′ 35	28.50′	57′ 0″	1° 47′ 56″	9″	78.54′	6.04′	56.88′
6	5.96′	20° 28′ 51″	25.50′	54′ 0″	1° 58′ 43″	8⅛″	78.54′	6.04′	54.79′
6	5.96′	20° 05′ 07″	25.50′	54′ 0″	1° 54′ 58″	8⅜″	78.54′	6.04′	53.83′
7	6.96′	16° 54′ 30″	27.25′	60′ 6″	1° 47′ 56″	9″	91.47′	7.04′	60.59′
7	6.96′	16° 43′ 42″	27.25′	60′ 6″	1° 58′ 43″	8⅛″	91.47′	7.04′	58.41′
7	6.96′	14° 30′ 54″	27.25′	60′ 6″	1° 58′ 43″	8⅛″	91.47′	7.04′	60.55′
7	6.96′	14° 15′ 21″	27.25′	60′ 6″	1° 54′ 58″	8⅜″	91.47′	7.04′	59.76′
8	7.97′	11° 16′ 27″	29.00′	67′ 0″	1° 47′ 56″	9″	104.41′	8.03′	67.87′
8	7.97′	12° 18′ 39″	29.00′	67′ 0″	1° 47′ 56″	9″	104.41′	8.03′	66.37′
8	7.97′	12° 08′ 09″	25.50′	63′ 6″	1° 58′ 43″	8⅛″	104.41′	8.03′	64.00′
8	7.97′	11° 54′ 18″	25.50′	63′ 6″	1° 54′ 58″	8⅜″	104.41′	8.03′	63.36′
10	9.98′	7° 14′ 18″	29.50′	77′ 0″	1° 47′ 56″	9″	130.33′	10.03′	77.11′
10	9.98′	7° 04′ 18″	27.00′	74′′6″	1° 58′ 43″	8⅛″	130.33′	10.03′	74.34′
12	11.98′	5° 13′ 50″	42.00′	99′ 0″	1° 14′ 15″	13″	156.27′	12.02′	99.46′
12	11.98′	4° 48′ 33″	29.00′	86′ 0″	1° 47′ 56″	9″	156.27′	12.02′	86.19′
15	14.98′	3° 05′ 50″	43.75′	115′ 0″	1° 14′ 15″	13″	195.22′	15.02′	115.23′
15	14.98′	2° 41′ 32″	27.75′	99′ 0″	1° 47′ 56″	9″	195.22′	15.02′	99.40′
16	15.99′	2° 39′ 15″	44.00′	120′ 0″	1° 14′ 15″	13″	208.21′	16.02′	120.15′
20	19.99′	1° 41′ 17″	54.50′	149′ 6″	0° 59′ 23″	16¼″	260.17′	20.01′	150.46′

to center of track. For other track centers add to or subtract from E, H, and X the quantity in

TABLE 20.—DATA FOR LOCATING TURNOUTS BY OFFSETS

1	2	3	4	5	6	7	8	9	10	11	12	13
Frog No.	Length of switch	Length of wing-rail	Total length of frog	Spread at toe of frog	Lead, L	Rails in main track	Rails in turnout	Radius of outer rail	A	Y₁	Y₂	Y₃
5	10'-0"	2'-11½"	8'-0"	0'-6½"	42'- 8½"	29'- 9"	30'-0"	175'-7½"	8'- 2½"	0'-11⅞"	1'-11 1/32"	3'-1 9/16"
6	15-0	3- 9	10-0	0-7	55- 7½	24- 0 12-10½	13-1½ 24-0	271-7	10- 1⅞	0-11⅞	1-10⅜	3-1½
7	15-0	3- 9½	10-0	0-6	61- 8	28- 0 14-10½	15-1½ 28-0	382-2¼	11- 8	1-0⅜	1-11	3-1⅞
8	15-0	4-10	12-0	0-6¾	67-10	24- 0 24- 0	24-0 24-2½	490-4¾	13- 2½	1-0⅜	1-11	3-2
9	15-0	4-10½	12-0	0- 6	71-10½	24- 0 28- 0	28-0 24-2	622-4	14-2⅝	1- 1	2-0	3-2¾
10	15-0	5-11½	15-0	0-6½	76-11½	26- 0 30- 0	30-0 26-2	807-5½	15-5⅞	1-1⅜	2- 0½	3-3
10	15-0	6-11	15-0	0-7¾	77-11	26- 0. 30- 0	30-0 26-0	767-7¼	15- 8¾	1- 1	1-11⅞	3-2⅝
12	20-0	7-0	18-0	0-6½	95-11¼	14-11¼ 26- 0 28- 0	28-0 26-0 15-0¾	1143-2¾	18-11 13/16	1-1⅛	2- 0	3-2¾
14	20-0	5-11½	20-0	0-4¾	107-11½	28- 0 28- 0 26- 0	26-1½ 28-0 28-0	1654-9½	21-11⅞	1- 1½	2- 0½	3- 3


Actual Point of Switch
Heel of Switch
Spread at Heel 5" for No.5 Frog and 6" for No.6 to 14 and 6¼" for Nos.15 and 18.
Actual Point of Frog
Y₁
Y₂
Y₃
4'9"
S
A
A
A
A
L
Offsets Y are Measured from Gage to Gage



No. 8 Turnout
(A)

No. 8 Crossover
(B)

FIG. 185.—Switch-ties.

229. Switch-stands.—A switch-stand is a device for throwing a switch by hand. It consists of a frame resting on the head-blocks of the switch and carrying a vertical rod having attached to it a hand-lever and being attached at the lower end, by means of a crank, to a throw-rod or connecting rod which is attached to the head-rod of the switch.

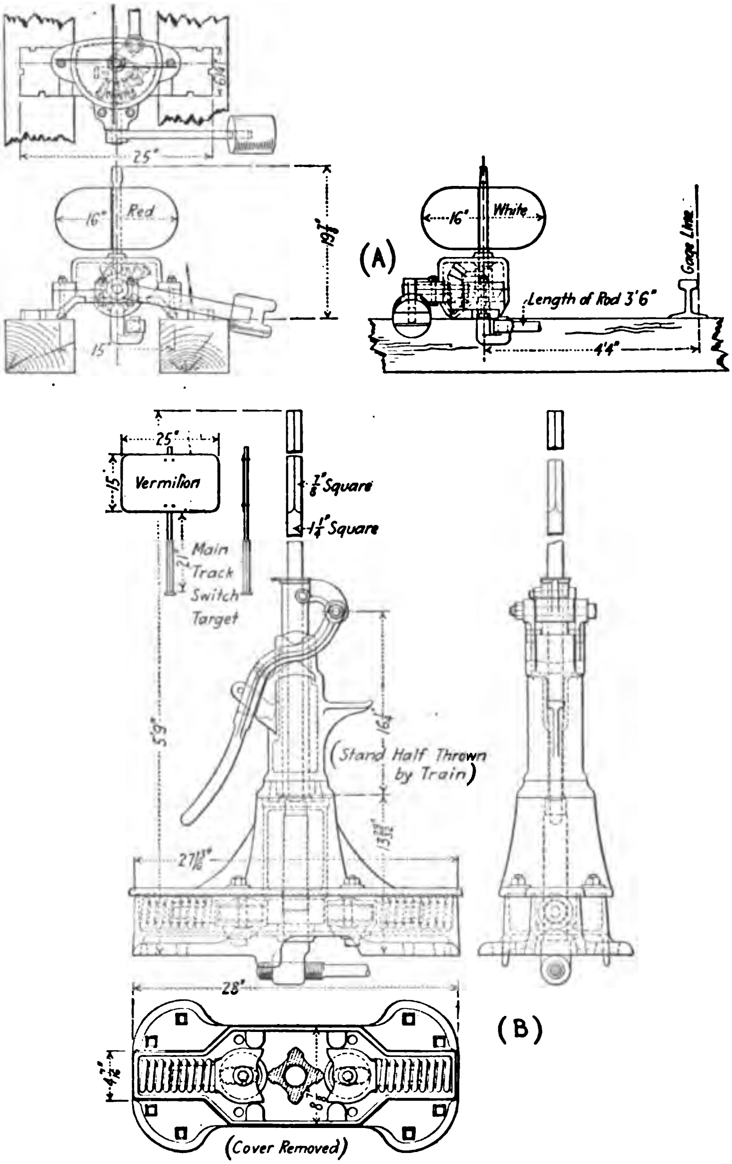


FIG. 186.—Switch-stands.

Interlocked or power-thrown switches require no switch-stand. The upper end of the vertical rod carries a banner or target, or two of these set at 90° with each other, which acts as a fixed signal to indicate the track for which the switch is set. The indication is conveyed at night by a switch-lantern placed above the banner and attached to the vertical rod. When two banners are used, one controls over the main line and the other over the turnout. A target of this kind always shows the location of the switch, while one blade does not. When the switch is set for the main track the banner governing over that track is parallel to the track and at night a white or green light is displayed to an approaching train. When the switch is set for the turnout the banner is turned perpendicular to the track and at night a red light is displayed to an approaching train on the main track. The hand-lever by which the switch is thrown is secured by a padlock in either position and must be unlocked by the switchman before the switch can be thrown. To throw the switch the lever is unlocked, raised to a horizontal position, and revolved horizontal. This revolves the vertical rod and through the crank gives a stroke to the throw-rod. Switch-stands of this type are from 5 to 9 ft. high. High mast or tripod switch-stands are sometimes used on main track. These have the banner mounted on a rod about 15 ft. high. In yards and at other points where clearance is limited or where high stands would be dangerous to trainmen riding on the sides of cars, low, dwarf, or ground stands should be used. These may be operated in the same manner as high stands or may have a lever which lies on the ground and moves through about 180° in a vertical plane parallel to the track. Through cranks or beveled gears this gives a stroke to the throw-rod.

There should be no lost motion in any of the parts of a switch-stand or the connection to the switch. The stroke of the throw-rod should be adjustable. The banner or light should not show clear for the main track unless the switch-point is snug against the stock-rail. Switch-stands with bolt locks are used by some railways. Two improved types of switch-stands are shown in Fig. 186: (*A*) is a low or ground-throw stand; (*B*) is the Ramapo "Safety" switch-stand, which has two coiled springs in a casting at the bottom of the stand. The stand is shown half thrown by a train. Instead of the switch-points remaining in the partly thrown position, the springs restore the rails to their proper position.

CHAPTER XVII

WORK OF THE MAINTENANCE OF WAY DEPARTMENT

230. Outline of the Season's Work.—There is a particular season in which each part of the work of maintenance of way and structures can be done best, and if not done at that season it will require more work when it is done. Because of this the work for each season should be outlined some time in advance. The large jobs of both track and bridge work cannot be done until authorized by higher officials, such as the chief engineer or the chief engineer of maintenance of way, and often these officials are responsible for a late start, with the accompanying disarrangement of the outlined work. However, it should be said that the fault lies in the system of financing and not in the higher officials of the engineering department. Allotments of rail should be made early in the year and the date of distribution fixed. Also it should be decided as early as possible what bridges will be renewed, and the bridge department should be notified accordingly so that in the meantime no permanent repairs will be made on the structures to be renewed. For similar reasons other heavy improvements, such as double-tracking, reballasting, widening banks or cuts, etc., should be authorized early. Many railways prepare a budget at the first of each year listing the work planned by all departments for the coming year, together with estimated cost. This budget should include only that work which is most necessary in each department and not all work that the officers of each department would like to have done. If the season's program is approved early the roadmasters and bridge supervisors are responsible for successfully carrying out the work. Extra gangs should be organized for the heavy work; the ideal condition would be to arrange all heavy work so that a permanent extra gang could be maintained until all work requiring an extra gang was completed.

Supervisors also should endeavor to get their section- and bridge-foremen to outline in advance their work for the season. The season's work on the section should be commenced at one end of the section and carried through to the other end, being started from the opposite end the next year. The least number of disturbed places in the track will occur if two section-gangs start at the same point and work in opposite directions. As the work of the season progresses the foreman occasionally should ride over his section on an engine and compare notes with the engineman concerning the condition of the track.

Early in the spring drainage is very important. As the frost leaves the ground shims must be changed. Tie-renewals can be made most easily immediately after the frost is out of the ground, while the track is still soft. This would necessitate distributing the ties the previous fall or in the winter or early spring. During the summer the right-of-way must be cleared of weeds. Late in the fall snow-fences must be repaired and placed and the final work done on the track to prepare it for the coming winter.

The expenditures of practically all railways reflect business conditions which exist at the time. This may never be changed, but it undoubtedly results in an uneconomical maintenance policy. It is expensive to defer maintenance from early spring until the middle of summer; and to defer it from one year to the next, because of business depression, is the climax of uneconomical maintenance. Putting off work from spring until summer means the loss of 1, 2, or 3 months at the best end of the season, which pushes the work into the winter. However, there are two reasons for doing this. First, business prospects may appear somewhat doubtful early in the spring, and the work is held up until a definite movement is apparent. Second, the fiscal year begins July 1. There is no good reason why July 1, instead of January 1, should be the beginning of the fiscal year, but as long as it remains as such, it will have much to do with the season in which maintenance work is done on many railways. The reason is that the year ends just in the middle of the maintenance season. The maintenance of way department finds itself out of funds just when maintenance work should be started in the spring and must postpone the work until after June 30, when the new appropriation will be available. This would not be the case if the fiscal and calendar years were the same.

231. Shimming.—During nearly half the year the railways in the larger part of North America must fight constantly the effects of frost. Practically no work can be done on the track during the winter on northern roads. The ballast freezes to a solid mass because of the moisture it contains, so that tamping, lining, and surfacing are practically impossible. The moisture contained in the ballast and roadbed freezes and, in expanding, lifts the track. The ballast at every point may not contain equal amounts of moisture; hence the expansion is not the same at all places. The result is that at some places the track bulges above the level of the rest of the track. This is called heaving; and, besides producing a rough-riding and often dangerous track, it causes severe stresses in the rails and track fastenings. Crossing planks, stock-guards, etc., are affected also, sometimes being heaved to such an extent as to catch the pilot of a locomotive. As moisture is the cause of heaving, drainage is the only remedy or cure. Additional work spent in summer on improving the drainage will reduce the amount of work in the winter spent on shimming. In order to meet the varying inequalities of heaved track, shims must be of different thicknesses. Every foot of shimmed track must be constantly watched and the watchfulness must be redoubled in the early spring when the track thaws in the day and freezes again at night. During weather of this kind the condition of the track changes hourly. When there are high spots in the track shimming must be carried out far enough on each side of the high spot to provide an easy grade. When one side of the track has heaved more than the other, the low side must be brought up on tangents, while on curves the proper superelevation must be maintained. When thick shims are used the ordinary spikes must be replaced with shimming spikes. When the shims are removed this procedure is reversed. If the track is tie-plated, plates with flat, corrugated, or shallow-flanged bottoms can be placed on top of the shims. However, with all but flat-bottomed plates it is best to place the shims on top of the tie-plates, which should not be disturbed. It is more difficult to maintain gage on shimmed track than on unshimmed track. Shimming is occasionally necessary in summer because of wet roadbed during very wet periods. The shims used are similar to frost-shims but are called mud-shims.

232. Ditching.—During the winter dirt accumulates in the side ditches in cuts and as soon as the snow disappears all ditches should be cleaned. This is a work of considerable magnitude and may be done by one of several methods. If the quantity of dirt to be removed is not large and the cut is shallow, so that the dirt can be thrown up to the top of the original ground, ditching by hand with a shovel is economical. By this method one man can handle 10 or 12 cu. yd. of dirt per day. Dirt should never be thrown on the slopes of the cut, as ensuing rains will wash it back into the ditch. On lines where there is very little traffic and where the amount of dirt to be handled is small the dirt may be shoveled on a push-car and taken out by hand. This costs more than the first method and can be used only on light-traffic lines. It is usually advisable to ditch large cuts on main line either by the work-train and extra gang or with ditching-machines. When the work-train is used the dirt is shoveled upon flat cars from which it is unloaded with a plow or by hand. The plow is more economical if a large amount of dirt must be moved.

After the first cleaning of the ditches in the spring, the section-foreman must watch them constantly and see that they are kept clean. In the fall all ditches and waterways should be gone over and given a final cleaning and put in repair for winter. Clean, deep ditches appreciably reduce the trouble from heaving. Particular attention should be given to the drainage at switches, frogs, interlocking plants, and railway and highway crossings.

233. Renewing Ties.—Starting in early April or late March, as soon as the frost is out of the ground and the section-crew is increased from a winter to a summer basis, the first work is that of renewing ties. The methods used to determine which ties are to be renewed were discussed in Arts. 58 and 59. In order to have the ties on hand when needed, those required for early spring renewals are distributed in the fall or winter. They should be piled on high ground where they will not interfere with the ditches. Piles of creosoted ties often are covered with a thin layer of earth as a protection from fire. The ties should be distributed as near as possible to where they are required. The cost of renewals is increased if the ties must be moved long distances by the sectionmen.

The old ties may be removed by digging them out or by jacking up the track 1½ to 2 in. and pulling them out. Digging out a tie disturbs the ballast under the tie and makes it more difficult to get the new tie firmly seated. Jacking up the track and pulling out the tie is easier, but if the ballast is composed of small particles it may run under the tie when the track is jacked up. If the old tie is of no further service it can be chopped into pieces with an axe and taken out without greatly disturbing the ballast. When a new tie is placed in the track it is measured by one of the men before it is spiked, to see that the end is the proper distance from the rail. Time will be saved if the foreman marks the tie beforehand with a chalk mark where the outer edge of the rail-base will come. When ties are being renewed they should be tamped at once to give as solid a bearing as that of the ties immediately adjacent, to preserve the surface of the track.

Ties removed from tracks in cuts should be hauled out of the cut to be burned. When renewing ties in yards the ties should be distributed the day needed and the old ties should be disposed of the same day. Any object lying by the side of a yard-track is dangerous to yardmen.

234. Renewing Rails.—Rail-laying should be started as early in the season as possible in order to be completed ahead of the general track work. It should be done at the recommendation of the supervisor of track, as he is in a better position than any other person to know the condition of the rails on his division. Badly worn rail in main track is dangerous and increases the cost of maintenance work.

The rails should be shipped on flat cars, rails of the same length being loaded together. Rails cut to special length for curves often are painted red on the ends. When the rails are unloaded they should not be placed on the end of the ties or in the ditches, but should be placed on the ballast or edge of roadbed and laid parallel with the track. Dropping rails off a car is a bad practice. When unloaded by hand they should be unloaded with skids from the side of the car or pulled off the end of the car upon an incline. Unloading by hand costs about twice as much as unloading by machine. Whatever method of unloading is used, the rails must be handled carefully and not allowed to fall on other rails or on hard or uneven ground. On busy track it is essential that every minor detail be worked out beforehand and that every man knows exactly what he is expected to do. The work can be done more economically if traffic can be diverted to another track while rail is being laid. Usually this is impossible. On some roads the frequency of trains allows only about 15 or 20 min. of continuous work, and at the end of that time the line of rails must be bottled up to provide an unbroken path for the train. Rail-laying is a menace to traffic because it necessitates making a break in the track. At all times the foreman must be in touch with the train dispatcher and flagmen must be kept out in each direction. The use of switch-points to make temporary connections between the new and old rail is often resorted to. It is not a safe practice and is not allowed on many railways. All defective ties should be renewed at the same time the rail is renewed and the track properly lined and surfaced as soon as possible after the rail is laid.

In removing the old rail two lines of spikes are drawn, if the old and new rails have the same section. Some supervisors draw the two inner lines of spikes and throw both old rails in. Others remove the two outer lines and throw both old rails out, while still others remove one inner and one outer line of spikes and throw one rail in and the other out. If switch-points are used for temporary connections both rails must be thrown out. If the new rail is of different section from the old, three lines of spikes must be drawn. As soon as the old rail is removed, the spike-holes are plugged and the ties are adzed to give an even bearing for the new rail. The new rails are then laid singly, allowing for expansion as discussed in Art. 110, the track is gaged, the splice-bars are applied with half the full number of bolts, and the rail is spiked to the shoulder-ties and second ties, sometimes to alternate ties. If the work is being done by a small gang the same gang will return later in the day and fully bolt all joints and spike all rails. If the gang is large it will be divided into squads which follow each other and perform the various parts of the work. The bolts of all joints should be carefully tightened to as near the same tension as possible in order to insure an equal movement of the rails when expanding or contracting. As soon as one or two new rails are in place the old rail is unbolted and placed on the roadbed outside the track. On very busy track it may be necessary to bolt up a string of rails on the ends of the ties and throw in the entire string at one time, instead of laying the rails singly. The work-train should follow closely after the rail-laying gang and should pick up the old rails, together with all scrap, and leave the right-of-way clean. It is even more economical to load than to unload the rails by machine. Before being loaded the old rails should be inspected for defects and all defective rails should be kept separate from the relay rails. The rails should be loaded in the order in which they were removed and when relaid an effort should be made to lay them in as near the original sequence as possible. In order to secure this result the rails sometimes are numbered with chalk or paint.

When renewing rails the general practice in the past has been to shift the joint- and shoulder-ties to correspond to the standard spacing of ties at joints, because the new joints practically never coincide with the old joints. The practice requires a large amount of extra work and disturbs the condition of the track to such an extent that a large amount of maintenance is required afterward to bring it back to its former condition. There is a growing tendency on the part of maintenance of way engineers to let the joints fall where they may without respacing the joint-ties. This is now being done on the Lehigh Valley, Pittsburgh and Lake Erie, and Illinois Central. The results have been most satisfactory. The cost of renewing rails is considerably reduced, the track is not disturbed, and more time and money are available for general maintenance and improvement of the track. Also it makes it possible to lay the rail in the winter when other track work cannot be done, and hence allows much more time in the summer season for other work.

TABLE 21.—MIDDLE ORDINATES IN INCHES, FOR CURVING RAILS

Degree of curve	Chord lengths in feet												
	100	50	33	30	28	26	24	22	20	18	16	14	12
1	2 1/2	5/8	5/16	1/4	3/16	3/16	1/8	1/8	1/8	1/16	1/16	1/16	1/16
2	5 1/4	1 1/4	9/16	1/2	7/16	3/8	5/16	1/4	1/4	3/16	1/8	1/8	1/16
3	8	2	7/8	11/16	5/8	9/16	7/16	3/8	5/16	1/4	1/4	3/16	1/8
4	10 1/2	2 5/8	1 1/8	15/16	7/8	3/4	5/8	1/2	1/2	3/8	5/16	1/4	3/16
5	13	3 1/4	1 7/16	1 3/16	1 1/16	7/8	3/4	5/8	9/16	7/16	3/8	1/4	3/16
6	15 3/4	4	1 11/16	1 7/16	1 1/4	1 1/16	15/16	13/16	5/8	1/2	7/16	5/16	1/4
7	18 1/4	4 5/8	2	1 11/16	1 1/2	1 1/4	1 1/16	7/8	3/4	5/8	1/2	3/8	1/4
8	21	5 1/4	2 1/4	1 15/16	1 11/16	1 7/16	1 3/16	1 1/16	7/8	11/16	9/16	1/2	5/16
9	23 1/2	5 7/8	2 9/16	2 1/8	1 7/8	1 5/8	1 3/8	1 1/8	15/16	3/4	5/8	1/2	3/8
10	26 1/4	6 1/2	2 7/8	2 3/8	2 1/16	1 13/16	1 1/2	1 5/16	1 1/16	7/8	11/16	9/16	3/8
11	29	7 1/4	3 1/8	2 5/8	2 1/4	2	1 11/16	1 7/16	1 3/16	15/16	3/4	5/8	7/16
12	31 1/2	7 7/8	3 7/16	2 7/8	2 1/2	2 3/16	1 13/16	1 9/16	1 1/4	1 1/16	7/8	5/8	1/2
13	34	8 1/2	3 11/16	3 1/16	2 11/16	2 5/16	2	1 11/16	1 3/8	1 1/8	15/16	11/16	1/2
14	36 3/4	9 1/4	4	3 5/16	2 7/8	2 1/2	2 1/8	1 13/16	1 1/2	1 3/16	1	3/4	9/16
15	39 1/4	9 7/8	4 5/16	3 9/16	3 1/8	2 11/16	2 1/4	1 15/16	1 9/16	1 5/16	1 1/16	13/16	5/8
16	42	10 1/2	4 9/16	3 3/4	3 5/16	2 7/8	2 7/16	2 1/16	1 11/16	1 3/8	1 1/8	7/8	5/8
17	44 1/2	11 1/8	4 13/16	4	3 1/2	3 1/16	2 9/16	2 3/16	1 13/16	1 7/16	1 3/16	7/8	11/16
18	47 1/4	11 7/8	5 1/8	4 1/4	3 11/16	3 3/16	2 11/16	2 5/16	1 7/8	1 9/16	1 1/4	15/16	11/16
19	49 3/4	12 1/2	5 3/8	4 1/2	3 7/8	3 3/8	2 7/8	2 7/16	2	1 5/8	1 5/16	1	3/4
20	52 1/2	13 1/8	5 11/16	4 3/4	4 1/8	3 9/16	3	2 9/16	2 1/8	1 11/16	1 3/8	1 1/16	13/16

Ordinates at the quarter points are 3/4 of the middle ordinate.

Rails on curves of 4° or over should be separately curved. Several railways curve rails on curves of over 2°. The curving is done by means of a rail-bender and care must be taken to see that the curving is uniform throughout the length of rail, and not in kinks. The proper amount of curvature is determined by stretching a string from end to end of rail and measuring the middle ordinate from the string, which acts as the long chord of the curve, to the rail. Table 21 gives the values in inches of middle ordinates for chords ranging from 12 to 100 ft. and for degrees of curvature from 1° to 20°. The degree of a curve can be found approximately by stretching a 62-ft. chord on the inside of the outer rail and measuring the middle ordinate. The middle ordinate in inches is the degree of curve.

The work of renewing rails requires a large force of men and usually is done by the extra gang. The number of men in the gang varies from about 25 to 250 or more and depends to some extent on the character of the track fastenings and to a large extent upon whether ties are respaced and the track lined and surfaced. If the track is laid with tie-plates, rail-braces, and rail-anchors these must be removed with the old rail and replaced when the new rail is laid. If tie-plates are not applied, track is not lined and surfaced, and ties are not respaced, a gang of twenty-five to thirty men is sufficient. The organization of a gang of fifty-eight men would be about as follows: one flagman out in each direction at all times gang is at work; two men taking up and putting down farm- and highway-crossing timbers and doing other odd jobs; one man looking after tools; four men pulling spikes; three men throwing out old rail; ten men adzing ties; twelve men putting in new rail; two men gaging; two men spiking joints and quarters; four men spiking; six men installing joints; one man handling thermometer and expansion shims; four men unbolting and setting out old rail; one water-boy; one foreman; two assistant foremen; one timekeeper.

The Lehigh Valley Railroad lays most of its rail with large gangs organized as follows:

	Foremen	Men
Removing rail-anchors	1	3
Pulling spikes	1	18
Throwing out old rail	1	10
Setting in new rail	1	24
Spiking	2	14
Drilling rails for bond-wires		10
Bonding		4
Installing and tightening joints	2	24
Applying rail-anchors	1	10
Motor-car on signal work and distributing water and light materials	1	3
Total	10	120

Two gangs of this size have been used on some jobs.

235. Ballasting.—It is the practice of most railways to raise or lift a ballasted track from 2 to 4 in. or more every few years. There are several reasons why this is done. (*a*) The work of general surfacing is done most easily by lifting the track and putting in a certain amount of new ballast. (*b*) There is also a certain settlement of the track resulting from disintegration and packing of the ballast and a loss of ballast over the shoulders and by being worked into the roadbed. (*c*) Old ballast becomes dirty and drains poorly. The common way, though not necessarily the best way, to improve the drainage is to lift the track and put a layer of fresh ballast over the old. (*d*) A further reason is that the weight of equipment and amount of traffic has gradually increased on most roads and from time to time it has been necessary to increase the depth of ballast under the tie.

Before the new ballast is distributed, all unsuitable material above the bottom of the ties should be removed to the full width of ballast and used to widen narrow embankments; defective ties should be replaced, all ties respaced, and the track brought to perfect line by track-center stakes set by the engineer or by track-center monuments. Ties can be respaced more rapidly if chalk marks are previously placed on the base of the rail where the center or edge of each tie should come.

The amount of ballast required must be carefully determined by the roadmaster. A greater lift than necessary is a waste of money. When the ballast is distributed it must not be mixed with old material. It must be unloaded uniformly and in such a way that it will not be wasted down the sides of the embankment. The ballast is unloaded either outside the rails or in the center of the track, depending upon whether it is unloaded with a plow or from side-dump or center-dump cars. While ballasting is progressing the length of open track prepared for the work should be reduced to a minimum and must be watched to avoid buckling. The bolts should be loosened if necessary.

If only a light lift is to be made, the work of reballasting can be done by the regular section forces, to which a few extra men may be added, or two or three section-gangs may be combined. Even for a heavy lift the size of gang required is less than for laying rail. After the ballast is unloaded and leveled the work of ballasting or reballasting consists of surfacing, smoothing up, and trimming. General surfacing is usually understood to mean lifting the track out of face to a uniform grade line. Smoothing up means the tamping up of low joints and centers to the general level. If the lift is over 4 in. the usual procedure is to bring the track to general surface by shovel-tamping all ties. After the track has been settled a few days by traffic it is gone over again and resurfaced or smoothed up, using tamping-bars or tamping-picks. The ballast is then trimmed to the standard ballast section, extra ballast is removed, and the work is finished. If the lift is in stone or slag ballast and does not exceed 4 in. the first surfacing usually is unnecessary and the ties are tamped with bars or picks. If the raise of the track is considerable, it is often done in two parts, as, for instance, a total raise of 10 in. might be done by making a raise of 7 in., and a final raise of 3 in. which is tamped carefully for final surface. It may be impossible to continue the lift through tunnels and bridges and adjacent to platforms, water-tanks, etc., because of limited clearance. At the end of the lift a gradual run-off must be provided.

The usual gang contains from 25 to 40 men. For a raise of 3 in. with stone ballast and 4 or 5 tie-renewals per rail, a gang of 30 men would be organized as follows: 4 jacks with 2 men each, jackmen putting in joint-ties; 8 men renewing ties back of jacks; 12 men tamping; 2 foremen. The organization of a gang of 10 men and foreman, for a 6-in. raise and a few tie-renewals per rail, would be as follows: 4 jacks with 2 men each, jackmen putting in ties in each half rail length; 2 men "catching up heads" or tamping ends of ties; at end of day's run the gang goes back and 4 men spike the ties and tamp inside the rail, and remainder of gang tamp outside the rail.

236. Surfacing.—The work of surfacing is continual. All parts of the track, and particularly the joints, must be watched constantly for low spots, and when these develop the low ties must be brought up to surface by tamping. After completing every kind of work on the track, more or less surfacing is necessary. The work of surfacing consists entirely of tamping, with the necessary manipulation of the track. Low spots are brought to surface by raising the track with track-jacks placed under the rail-base and outside the rail. The track is lifted until the top of rail is at grade and ballast is then tamped under the ties.

The first work of the section-gang in the spring after removing shims, is to go over the track and give the track a general running surface. By this is meant the work done to bring the track to an easy-riding surface by tamping up the low places, not much attention being given to the general surface. General surfacing must follow reballasting, laying rail, etc. One tie showing excessive rail-cutting often is an indication of lightly tamped or low adjacent ties.

In raising track both rails always should be raised simultaneously, and by the same number of jacks under each rail, the jacks being placed opposite. When surfacing is completed, the two rails on tangents must be at the same elevation. This should be determined by using a track-level. If at any time the difference in elevation of the two rails exceeds 3/8 in. the track should be resurfaced at once.

With labor at $1.50 per day and foremen at $75.00 per month, surfacing costs from about $275 to $375 per mile of track, the cost being affected by the kind of ballast, size of gang, and depth of raise. One man can surface from 20 to 30 lin. ft. of track per day. The cost of surfacing for a running surface, smoothing up, and trimming is from $75 to $125 per mile for each.

The proper tamping of ties is perhaps the most important part of all track work. The tools used are shovels, tamping-bars and tamping-picks. Different kinds of ballast require different methods of tamping. The first tamping is usually done with a shovel. The final tamping should be done with a bar or pick, but it is not advisable to do this with burnt clay ballast not properly vitrified. In general, a tie is thoroughly tamped for several inches on each side of the rail and is not tamped at all or only very lightly tamped at the center. The American Railway Engineering Association recommends that ties be thoroughly tamped from 15 in. inside the rail to the end of tie. The rules of the Canadian Pacific Railway and the Frisco Lines require ties to be thoroughly tamped for 16 in. on each side of the rail. The practice on the Boston and Albany Railroad is to thoroughly tamp each tie for 12 in. on each side of the rail; from 12 in. outside the rail to the end of tie the tamping is done lightly, and the center is not tamped at all. The parts of a tie outside the rails should be tamped first and the inside should be tamped later, after the passage of a train. Ties in new track are tamped uniformly for the full length, but in old track this would tend to produce a center-bound track, which would cause the track to rock under the passage of a train. Joint-ties and second ties should be tamped particularly hard. As no two men tamp a tie alike, the same man should tamp the heads or ends of all ties at one joint.

237. Superelevation.—As far as safety is concerned the actual amount of superelevation of the outer rail on curves, even for high speeds, is relatively unimportant. Of more importance are (1) the use of specially secure rail-fastenings, (2) plenty of ballast outside the curve to prevent the track from being thrown out, (3) maintaining a uniform and even line and surface, and (4) providing a long run-off for the superelevation.

The rate of the run-off determines the length of the spiral. A rule used frequently is to decrease the elevation at the rate of ½ in. per 30- or 33-ft. rail. On the New York Central Lines the rate of run-off is at the rate of ¼ in. per 30 ft. for elevations of 3 in. or under; for elevations over 3 in. the maximum length of run-off is limited to 360 ft.

The elevation required is a function of the speed and degree of curve.

Let e = elevation of outer rail in feet at gage line,
E = same elevation expressed in inches,
G = gage of track in feet = 4.708,
D = degree of curve,
R = radius of curve in feet = $\frac{5730}{D}$ (approximately),
V = velocity in miles per hour,

and

$$v = \text{velocity in feet per second} = \frac{V5280}{3600}.$$

Then the approximate formula for elevation is,

$$e = \frac{Gv^2}{32.16R} \qquad (237a)$$

or,

$$E = 0.00066V^2 \qquad (237b)$$

The values of the theoretical superelevation, as found by formula 237*b*, for velocities from 10 to 70 miles per hour and for curves from 1° to 20°, are given in Table 22.

TABLE 22.—ELEVATION OF OUTER RAIL ON CURVES

Degree of curve		Speed in miles per hour													Degree of curve
		10	15	20	25	30	35	40	45	50	55	60	65	70	
1	Elevation in inches	0	⅛	¼	⅜	⅝	¾	1⅛	1⅜	1⅝	2	2⅜	2¾	3¼	1
2		⅛	⅜	½	⅞	1⅛	1⅝	2⅛	2⅝	3¼	4	4¾	5½	6½	2
3		¼	½	¾	1¼	1¾	2⅜	3⅛	4	4⅞	6	7⅛	......	......	3
4		¼	⅝	1	1⅝	2⅜	3¼	4¼	5⅜	6⅝	8	......	......	......	4
5		⅜	¾	1¼	2	3	4	5¼	6⅝	......	......	......	......	......	5
6		⅜	1	1⅝	2½	3½	4⅞	6¼	8	......	......	......	......	......	6
7		½	1⅛	1⅞	2⅞	4⅛	5⅝	7⅜	......	......	......	......	......	......	7
8		½	1¼	2⅛	3¼	4¾	6½	......	......	......	......	......	......	......	8
9		⅝	1⅜	2⅜	3¾	5⅜	7¼	......	......	......	......	......	......	......	9
10		¾	1½	2⅝	4⅛	5⅞	......	......	......	......	......	......	......	......	10
11		¾	1¾	2⅞	4½	6½	......	......	......	......	......	......	......	......	11
12		⅞	1⅞	3⅛	4⅞	7⅛	......	......	......	......	......	......	......	......	12
13		⅞	2	3⅜	5⅜	7¾	......	......	......	......	......	......	......	......	13
14		1	2⅛	3⅝	5¾	......	......	......	......	......	......	......	......	......	14
15		1	2¼	3⅞	6¼	......	......	......	......	......	......	......	......	......	15
16		1⅛	2½	4¼	6⅝	......	......	......	......	......	......	......	......	......	16
17		1¼	2⅝	4½	7	......	......	......	......	......	......	......	......	......	17
18		1¼	2¾	4¾	7½	......	......	......	......	......	......	......	......	......	18
19		1⅜	2⅞	5	7¾	......	......	......	......	......	......	......	......	......	19
20		1⅜	3	5¼	......	......	......	......	......	......	......	......	......	......	20

In many cases it is not practical to provide the theoretical elevation because trains of different speeds must use the same track. It is seldom advisable to use more than 8 in. elevation. On maximum grades the elevation should be less than elsewhere because of danger to slow trains. The maximum elevation on several railways is as follows: Canadian Pacific, 6 in. on single track; Frisco Lines, 7 in.; Pennsylvania, 7½ in.; New York Central Lines, 8 in.

The amount of elevation should be governed by the class of the majority of traffic. If the freight traffic is most to be considered the elevation should fit the freight-train speed, the freight-trains should be handled with their maximum tonnage rating, and the passenger-trains must be run at restricted speed around the curve. If it is more important to maintain the speed of passenger-trains than to handle the maximum tonnage with freight-trains, the elevation can be made to fit the speed of passenger-trains. This may necessitate a slight reduction of the tonnage of freight-trains, and the wear of the inner rail from the action of the slow-speed trains is excessive. It is more difficult to determine the elevation for single track than for double track. On single track an elevation for a train going up a grade will be entirely wrong for the same train going down the grade and the proper elevation is the mean between the two. Where a train stops on a curve every elevation is wrong. Tracks used exclusively for storing cars should have no superelevation, and very little, if any, should be used in yard-tracks.

The universal practice is to keep the inner rail to grade and elevate the outer rail the full amount. Certain advantages might be gained by lowering the inner rail half the full amount and raising the outer rail an equal amount. In attaining the superelevation the locomotive lifts the total weight of the train through a vertical distance equal to half the superelevation. If the inner rail was depressed by the same amount that the outer rail was elevated, this resistance would be zero. The objection appears to be all from the maintenance standpoint; the depth of ballast would be decreased under the inner rail and some trouble would arise in transferring elevations from the true grade to either rail.

238. Lining.—Track should be lined to center stakes set by transit. The work should be so arranged that a minimum movement of track is necessary. Tangents may be thrown between summits or between curves, or the tangent may be moved half the necessary distance and the curve the same distance in the opposite direction, or the curve may be thrown to meet the tangent.

Transition curves or spirals should be used on all curves having a superelevation of 2 in. or more and at points of compound curvature where the difference in elevation of the two curves is 2 in. or more. The length of the spiral is roughly determined by the rule for rate of run-off given in the preceding article. Nothing is gained by using very long spirals. Any form of transition curve is satisfactory which, for chords of any length, can be run in both by deflections and by offsets, and in which the degree of curve increases with the distance.

At all changes in direction of alignment permanent monuments must be placed, which will enable the line to be rerun at any time.

239. Gaging.—The maintenance of gage depends on the rail being held firmly to the ties so that there is no tendency for it to roll or overturn, and the strength of the wood of the ties to resist crushing endwise of the fiber and allowing the spikes to be pushed outward. Spikes are assisted in holding gage by the use of rail-braces and shoulder tie-plates. Shoulder tie-plates are preferable to rail-braces.

The maximum allowable variation from standard gage, as a result of rail wear and the tendency of the rails to roll, is ½ in. wide and ⅛ in. narrow. Any variation should be allowed only where it is uniform for some distance. Short irregularities cause wobbling of the trucks and rough riding.

Laying rail to standard gage is more difficult than might be supposed, because the settlement of the rail to its final position on the tie is not always in a direction parallel to the rail-web. When rail is being laid, a top gage or a top and bottom gage may be used. The top gage generally is used but in some cases better results have been obtained by using both. In either case rail laid on new ties may require regaging after it settles into place. This difficulty is not so pronounced on machine-adzed or on sawed ties, but on hand-adzed ties it is often found that the rail actually inclines slightly inward, even when tie-plates are used. In such a case either a head- or base-gage gives incorrect results. On machine-adzed ties excellent head-gage has been obtained by relying entirely on the base-gage. On sharp curves it is necessary to slightly widen the gage. The American Railway Engineering Association recommends that all curves 8° and under have standard gage, and that gage be widened ⅛ in. for each 2° over 8°, to a maximum of 4 ft. 9¼ in. The Pennsylvania Railroad uses standard gage up to and including 10° curves; for sharper curvature the gage may be widened not to exceed 4 ft. 9 in. On the other extreme the Canadian Pacific and Canadian Northern widen the gage by increments of ⅛ in. from 3° to 4°, 5° to 6°, 7° to 9°, 10° to 12°, 13° to 15°, and 16° to 20°. The Philadelphia and Reading increases the gage by ⅛ in. for each 2° from 5° to 13°, while the New York Central Lines increase the gage by increments of ¼ in. from 6° to 10°, 10° to 14°, and 14° to 16°.

240. Clearing, Cleaning, and Policing.—All grass, weeds, and brush on the right-of-way should be cut about July 1, or before the seeding time of the plants. All cut material should be burned as soon as dry. It may be raked into piles and burned or burned by dragging over it a piece of oil-soaked burning waste at the end of a wire. Several railways mow the right-of-way before July 1, and again in August or September. Level ground can be cleared with a mower and team at a cost of about $10 per mile. When burning the material only one side of the right-of-way should be burned at a time and this should be done when the wind blows from the adjacent property. Great care must be taken to see that the fire does not spread to adjacent land and does not damage fence-posts, telegraph-poles, and signs. One or two furrows plowed inside the right-of-way fence often prevent the spreading of fires started within the right-of-way from sparks. Stumps should be removed at odd times and all combustible material should be collected and burned. All metal scrap should be collected, sorted, and stored for further disposition. Trees, brush, and other obstructions that tend to obscure the view of a sign, bridge, or crossing as seen from an approaching train, or from an approaching vehicle on a highway, should be removed. At all times vegetation and other combustible material should be kept cleared from under trestles and wooden bridges and around stock-guards, poles, posts, platforms, buildings, and highway crossings. Weeds must not be allowed to grow in the ballast and the side ditches must be kept clear of vegetation. At least twice each year on all ballasted track the sod should be trimmed to a true sod line outside the toe of ballast, or entirely removed from the roadbed, according to the practice of the railway in allowing sod on the roadbed. Trees near telegraph-wires must be kept trimmed to prevent branches from touching the wires during high winds.

Station-grounds should be cleaned at least twice a week and all paper and other rubbish picked up. If a parking is maintained, the grass must be watered and mowed as required. When cleaning in yards, piles of dirt must not be allowed to remain between tracks because of danger to trainmen. If the ballast will not be fouled by so doing, the dirt can be piled in the center of the track and picked up from there by the work-train. Much dirt accumulates around freight houses and on certain yard-tracks on which cars are cleaned. If the organization of the freight house or yard does not provide for removing this dirt, it must be cleaned up at intervals by the section-gang.

The fire laws of the particular State or Province must be carefully observed at all times, and noxious weeds must be exterminated. The fire laws of Massachusetts require sectionmen or other employees of a railway to act as fire-wardens in extinguishing fires burning on lands adjacent to the right-of-way.

The foreman should select the most intelligent man of his crew to act as track-walker. The track-walker must be familiar with the rules for track work and flagging. He should examine every switch, switch-stand, frog, and guard-rail each day; should tighten any loose bolts; drive down any loose spikes; reset or remove any crossing planks heaved by frost; temporarily repair any broken fences; close farm gates which he finds open; watch the track for spreading; be on the lookout for trespassers, especially around wooden bridges, and continually watch for abnormal conditions of the railway property and private property adjacent thereto.

241. Miscellaneous Maintenance Work.—Besides the general maintenance work already discussed, many odd jobs must be done, and there is much work which must be done repeatedly during the year. Loose bolts must be tightened and raised spikes redriven. Rails, splice-bars, bolts, spikes, etc., are liable to break at any time and must then be replaced. Low joints constantly develop and when observed must be tamped up to surface. The rails must be watched for creeping. The mechanism of uninterlocked switches must be kept in perfect working order, and switch-lights must be lit at night and extinguished in the morning. Waterways must be kept open. The water-barrels on bridges must be kept filled; in dry weather it may be necessary to stop local freight-trains to fill these. Finally, all other work which is necessary to prevent deterioration of the property must be done.

242. Inspection of Track.—It is customary for the officials of a railway to make a general inspection of track at least once a year. When one general inspection is made, it is called the annual inspection of track and is made in the fall after the summer's work is completed and the track brought up to its best condition in preparation for the winter. The inspection party is usually made up of the maintenance of way engineers, together with officials from other departments, often including the general manager or general superintendent. Besides the actual determination of the condition of the track, these inspection trips have a marked educational value. The men of the different divisions, districts, and departments are brought together, giving an excellent opportunity for the discussion of maintenance of way subjects and for the men to see what and how work is done on territory other than their own. The men of the inspection party are divided into committees each of which inspects and grades certain features. Usually the grading is done by miles. The best section on each supervisor's division and the best supervisor's division are determined, and prizes of various kinds are awarded accordingly. This tends to develop a rivalry among men on different sections and different divisions and to keep every person working at his best.

The benefits derived from the annual inspection have been so pronounced that several railways have appointed regular committees which make inspections at intervals of 1 or 2 months during the summer. Under this system the best section and division is the one which, after the final inspection in the fall, has the highest average grade of all inspections. The Pennsylvania Railroad distributes about $10,000 yearly in premiums to trackmen. The highest prize is $1200, $800 of which is given to the supervisor and $400 to the assistant supervisor of the best division. The supervisor and the assistant supervisor of the division which shows the greatest improvement during the year receive $700 and $300, respectively.

The grades of the various features generally are based on the judgment of the men making the inspection. Several mechanical devices have been developed as an aid to the judgment of the inspectors. The condition of the track is very largely indicated by the number and magnitude of the vibrations of a moving car. The Pennsylvania Railroad now equips the inspection-car with a simple form of seismograph which automatically records the number and intensity of all horizontal and vertical vibrations of the car.

The inspection-car used by the Grand Trunk Railway is fitted with an observation end having seats for five men at a desk across the end of the car. On the desk are placed ten sets of push-buttons electrically connected to ten numerical indicators above the rear windows. The indicators represent respectively, line; surface; joints; spacing of ties; drainage of banks and ditches; ballast; station-grounds, policing and fencing; buildings; spikes; and sidings. Each of the five inspectors seated at the desk is responsible for two of these features. Each indicator registers from 0.1 to 9.9. The grading is done per mile and is on a basis of 10 as perfect. At each mile-post the supervisor of that division calls the number of the mile-post and the inspectors push the buttons and register the grades for the mile just passed. The grades are copied by a clerk and later the average grade of each section is computed. The car travels at a speed of about 25 miles per hour. Several other railways are using similar inspection-cars.

Besides the general inspection, it is the duty of the roadmaster and division engineer frequently to ride over their territory on fast trains and note the location of rough track. This information is at once conveyed to the sectionmen so that the defects will be remedied. Devices are in use which record graphically on a continuous roll of paper the variations in gage and surface of the track. The difficulty with a record of this kind is for the trackmen to take the strip of paper and locate on the track the bad places shown on the record. One way to actually mark the bad spots is to equip a car with an apparatus which, at the will of the operator, squirts a small amount of whitewash on the rail at points to which it is desired to call the attention of the trackmen.

A few railways have a special inspection made of rail. One device used slides on the rail and carries a mirror on each side of the rail mounted in such a way that the man who pushes the device can see the reflection of the under side of the rail-head in the mirrors.

243. Maintenance of Way Painting.—In general, the maintenance of way painting can be handled in one of four ways: (1) All painting may be done by a traveling gang of experienced painters. (2) The work of painting derails, switch-stands, targets, etc., and minor structures may be done by the section forces. (3) The painting of new structures and repair work may be done by the carpenters. (4) The painting may be done by locally hired painters.

The traveling paint-gang should be divided into two classes of painters, one for steel structures and one for timber structures. Many persons believe that painting can be done by anyone. As a rule, the skilled painter can get better results with a poor quality of paint than an inexperienced man can get with the best of materials. Paint should never be applied in wet or freezing weather, though by thinning the paint with turpentine and properly brushing it on, an experienced man can do good work in cold weather.

The surface of structural steel to be painted must be thoroughly cleansed of all scale, rust, dirt, etc. Only an experienced painter, and one experienced on steel work, will do this. The old coat of paint must be entirely removed if any trace of corrosion is apparent under it. The surface may be cleaned with hammer and chisel, wire brush, sand blast, or by scraping. Cleaning by sand blast is the most expensive and has been little used, but is the most effective.

Plaster and cement walls subject to moisture should be given a first coat of some varnish-like filler which will make the surface waterproof. The paint is applied over this. Walls having a hard surface should first be gone over with a wire brush. Concrete floors should be given a similar treatment of brushing and painting. If the wall is not exposed to moisture, a wash of zinc sulphate should be substituted for the water-proof filler. This changes the free lime at the surface to sulphate of lime and prevents the saponifying action of the free lime on the paint. The date of painting a bridge or a building and the designation of the paints used should be plainly indicated at a place on the structure where it will not be obliterated.

244. Inspection of Bridges.—Every bridge should be inspected thoroughly at least twice a year, once in the spring and once in the fall. A few light-traffic roads omit the spring inspection and many heavy-traffic roads require additional inspections. Bridges are inspected once a month on the New York Central Lines. When less frequent inspections are required, all structures should be inspected in a general way each month by section- and bridge-foremen. If frequent inspections are required, they are made by special bridge-inspectors. Otherwise the fall inspection is made by an engineer of the bridge department in company with the supervisor of bridges and buildings or the master carpenter, and the spring inspection is made by the supervisor alone. The notes as to condition of the structure should be recorded at the structure during the progress of the inspection. The inspector should have with him the notes of the previous inspection and ordinarily it is necessary to take notes only to show any change in the condition of the structure since the last inspection, and whether the repairs recommended at the last inspection have been carried out properly. If the inspector considers immediate attention necessary he should at once call in the services of the nearest section-gang.

The spans, bents, or piers of a bridge or trestle should be designated by numbering them in the direction of the bridge-numbers, commencing with No. 1 at the abutment, back bent, or sill. The panels of a truss-bridge should be numbered in the same way. Trusses should be designated as right or left according to the direction of the bridge-numbers.

The most important points to be inspected in a steel bridge are the following: (1) The rollers must move freely, be at right angles to the line of the bridge, and be free of cinders or rubbish. (2) Posts and compression members must be free from bends or bulges, and all joints must have a firm and even bearing against each other. (3) Tension members must show no slackness and should be adjusted so that they will be equally stressed in any panel. Rods must be adjusted when there is no live load on the bridge. (4) Floor beams and stringers require careful examination for flaws in connecting angles, for defective, loose, or missing rivets, and for shearing and crushing of webs and flanges at connections. (5) All riveted members should be tested with a hammer to detect loose rivets, and if any are discovered they should be marked plainly and replaced as soon as possible. (6) Bridge seats must be examined for cracks or evidence of crushing, and to see that they are level. (7) The structure should be carefully watched under the passage of trains. Swaying, excessive deflection, twisting, and rattling of members is evidence that attention is necessary.

Retaining walls, culverts, piers, abutments, and other masonry structures must be examined for undermining, scouring, bulging, settling, or other movement, cracking, or other defect or dangerous indication.

As the deterioration of timber is more rapid and erratic than that of metal, timber bridges require careful and frequent inspection. Three general methods may be used for determining the condition of the timber. These are by (1) sight, (2) sound, and (3) boring. The appearance of the timber on the outside is not an accurate gage of the condition of the interior. The general condition of the timber can be determined best by sounding, which consists of striking the timber with a hammer weighing about 5 lb. Timber which does not sound right should be tested by boring with a small bit, or by the penetration method, a modification of boring. Boring should be done only in very doubtful cases. When boring is necessary, a hole is bored with a ⅜-in. bit, and the chips are examined for the desired information. The hole should be at a place where the strength of the timber will not be weakened and should be plugged immediately afterward to prevent the entrance of water. A sharp-pointed steel rod or thin-bladed knife may be used for penetrating the timber. These are driven into or thrown against the timber and the amount of penetration indicates the condition of the interior. Long rods of this kind are particularly useful for inspecting interior angles or surfaces of the structure which cannot be reached otherwise.

Bents of trestles must be plumb. Piles should be particularly examined at the water line and should be excavated at the ground line to determine the condition below the ground surface. Weak stringers and settling piles can often be located by examining the structure under a passing train. All parts should be examined for defective joints or pulling apart. Old trestles should be given careful attention and inspected frequently. Ballast-floor bridges also require careful inspection.

The inspection should also include the condition of waterways adjacent to the structure, whether these need enlarging or cleaning out, whether the waterway is insufficient, and whether the shoulders of the embankment need to be riprapped. Clearance lines must be examined carefully. The condition of line, surface, rail, rail-joints, and fastenings on and adjacent to the structure must be examined in a general way, and it must be seen that the bedding of tracks on supports is such that there will be no jar when the train passes from the bridge to the roadbed, or *vice versa.* The condition of drain pipes and open drains, abutments of bridges and structures, proper insulation of electrical attachments, and the condition of the paint must also be examined.

Movable bridges should be inspected personally, and at frequent intervals, by the supervisor of bridges and buildings or by the engineer of bridges. Additional parts of the machinery which are subject to greatest wear or are most liable to break should be kept close by for emergency purposes.

245. Inspection of Buildings.—All parts of structures should be thoroughly inspected. The parts which should be given particular attention are the hidden supports of buildings and platforms, roof-trusses of shops, smoke-jacks, water-tank hoops, and the members of all structures subject to the blast from locomotives or the corrosive action of locomotive gases. An especial effort should be made to keep all buildings used by the public neatly painted and properly maintained. The sanitary conditions should be perfect at all times. Small defects such as broken glass, locks, and woodwork should be promptly repaired.

246. Winter Maintenance Work.—Most maintenance work is done during the summer. Much of this could not be done in the winter, while some could be done as well in the winter as in the summer. The practice of laying rail in the winter, followed by the Lehigh Valley (Art. 234) is an example. By putting off for the winter all work that can be done in that season, the winter and summer work will be made more nearly equal and a more permanent and better maintenance of way organization will be obtained. Regaging track and repairing fences requires considerable time and in most cases can be done as well in winter as in summer.

In addition to the usual routine work the winter duties of the section-gang include the patrolling of tracks and constant vigil to detect broken rails and splice-bars; shimming rails; the care of outlying switch- and signal-lamps, and keeping the lenses of these clear of snow; shoveling snow from tracks that cannot be plowed; the removal of snow and ice from frogs, switches, water stations, track-scales, flangeways at crossings, signs, buildings, turntables, and ash-pits; and the removal of ice from the sides and roofs of tunnels and the sides of rock cuts. Occasionally it is necessary to shift the position of portable snow-fences, as the direction of the prevailing wind may change or the fences may not have been properly placed at first. During the winter additional tools and supplies such as snow-shovels, salt for switches, sand, rattan brooms with chisel-end handles, track-shims, common spikes and shimming spikes, rail-braces, etc., must be kept at the section tool-house.

Roadmasters and certain of the section-foremen are required to report the weather conditions each morning to the division headquarters.

247. Removal of Snow and Ice.—The success with which a railway in northern climates is kept open during the winter depends largely on the advance preparation and organization. All snow-fighting equipment must be repaired early in the fall, and at the same time the additional tools and supplies should be distributed to the section forces. The equipment required is all or several of the following: flangers, push-plows, pilot-plows, rotary plows, snow-crabs, levelers and spreaders.

The first snow causes little trouble and the rails can be kept clean by using flangers or pilot-plows. Serious trouble commences when the track in places becomes grooved between two banks of snow. The use of flangers causes a ridge of snow or ice to form along the center of the track, which must be removed by a snow-plow. During storms a snow-plow should be run ahead of every train. Three or four locomotives may be required back of the plow if the drift is deep. The push- or wedge-plow requires a speed of 35 miles or more per hour to clear the track, and if the drift is solid, "bucking" must be resorted to. This is destructive to the machinery and dangerous to the men. The rotary plow is the best for deep drifts. It should be run at a speed of 3 or 4 miles an hour. The snow cut must be widened when the banks of snow on each side of the track begin to reach such a height that it is difficult to operate a plow. This is done with a snow-crab, which drags the snow from the side walls into the center of the track, a plow then throwing it clear of the snow cut.

Salt is used at switches and frogs to prevent freezing of movable parts and to keep flangeways open. As it rapidly corrodes iron, it should be used only as occasion demands, and should never be used at interlocking plants. Salting switches or frogs is beneficial only when the temperature is such that the snow melts during the day and freezes at night.

Other methods used to keep switches open in winter are the burning of hydrocarbon and the installation of steam-pipes at the points of switches. The tracks of the Erie Railroad at the Jersey City terminal and of the Canadian Pacific Railway at the Windsor Street Station, Montreal, are equipped with steam-heating pipes.

248. Work-train Service.—The principal feature in the operation of a work-train is to keep the machine working every possible minute. At best much time is lost in dodging other trains. In many instances time can be saved if the engine is equipped with a water-car and fire-cleaning tools, so that it can lay over one night between terminals. The efficiency of the work-train depends primarily upon the foreman and the conductor. If the conductor has had maintenance of way experience he will be able to handle the work-train to much better advantage. When possible the supervisor should accompany the work-train. The best results are obtained by having a train-crew, consisting of an engineman, fireman, and conductor, regularly assigned to the work-train. The actual work of loading, unloading, etc., is done by an extra gang of laborers. The number of laborers employed depends on the kind and magnitude of the work. It is seldom advisable to have less than twenty laborers when the work is sufficient to require a work-train. Comparatively small gangs are required for ballasting, distributing ties, etc., while a large gang is required for ditching, handling rail, etc. A gang of from thirty to sixty men can be used on ditching when the work is done by shoveling to flat cars, about six men being required per car.

Each day the supervisor should furnish the conductor with a written outline of the program for the day. A tentative schedule should be made up and the work-train operated on it as near as possible. The work should be planned in such a way that it will be continuous and progressive in one direction. The foreman should be required to make a written report of the work done each day and the amount and reason for delays sustained.

There is not always sufficient work to require a regular work-train throughout the summer, but when the magnitude of the work warrants it, a regular work-train is far more efficient than the special work-train ordered out for 1 or 2 days at a time. The greatest advantage of the regular work-train is that it permits a permanent organization of the extra gang accompanying it. Way freights are sometimes used to perform the functions of a work-train. This is uneconomical if the work requires more than one or two trips. When traffic is light in one direction it may be possible to have a good part of special work-train service handled by light power.

While using work-trains the maintenance of way department must keep in close touch with the operating department. Though the work done by the work-train is under the control of the maintenance of way department, the general movements of the train are controlled by the train dispatcher. When it is desired to order out a work-train, the supervisor must assemble sufficient material for at least 1 day's work, and then must notify the chief dispatcher of that division that on a special date a work-train will be required, also stating at what point work will commence, the length of time required between stations, the character of the work to be done, and approximately how many miles of line will be covered that day. If the work consists of handling and spreading ballast a heavy engine in good condition is necessary and in notifying the dispatcher the supervisor should so inform him. If the work is such that a light engine can do it the supervisor also should so inform the dispatcher. The supervisor is then more likely to get the heavy engine when he really needs it. On the day the train goes out, each section-foreman should meet the train at the end of his section with a list showing the material required for each mile and as near as possible the exact position where the material should be unloaded.

As the movements of the work-train are under the general supervision of the dispatcher the cost of distributing the maintenance material is very largely affected by the attention or neglect which that official gives the matter. If the train is scheduled to go out at 7 A. M. and the maintenance gang which is to accompany the train is on hand at that time but the engine is not ready or the train is held on a siding until 8 o'clock to let other trains pass, the maintenance work is not only delayed but the company has lost perhaps 20 to 40 or more man-hours at 20 to 30 cents per hour. Also, without proper watchfulness on the part of the dispatcher it may happen that the work-train no sooner gets out on the work than it is driven in by another train. This means a loss to the company of from 1 to 3 hr. for the entire crew of the work-train.

The foreman on the train should watch closely the work of unloading material. Rails, ties, etc., should never be unloaded in such a way that they will roll down an embankment. While frogs, switches, etc., are being unloaded, special care is necessary to prevent bending them. The constant aim of the work-train crew while unloading any material should be to reduce to a minimum the subsequent work of the section-gang. The equipment of a work-train depends entirely on the work for which the train is ordered out. For whatever purpose the equipment is needed it should consist of every possible labor-saving device, so that manual labor can be reduced to a minimum. The most important and most expensive devices necessary are steam-shovels, steam-cranes, ditching-machines, rail-handling machines, pile-drivers, unloading-plows, ballast-spreaders, special ballast and earth dump-cars, and snow-plows.

The use of work-trains in the bridge and building department usually is for the purpose of handling heavy girders, concrete slabs, or masonry, or for driving piles.

CHAPTER XVIII

ROADWAY MACHINES—SMALL TOOLS AND SUPPLIES

249. General Classification.—The classification of railway expenses prescribed by the Interstate Commerce Commission, effective July 1, 1914;

TABLE 23.—LIST OF TOOLS FOR SECTION-GANGS

Tools	Foreman and		
	3 men	5 men	10 men
Adzes, with handles	2	2	4
Axes, chopping, with handles	1	1	1
Ballast-forks (stone or slag ballast only)	3	4	8
Bars, claw	2	3	4
Bars, lining	3	5	8
Bars, tamping (gravel, stone or slag ballast)	4	6	8
Brooms, rattan, switch	2	2	2
Cans, oiler, hand-car	1	1	1
Cans, 1-gal. oil	1	1	2
Cans, 5-gal. oil	1	1	1
Cars, hand (insulated if used with track circuits)	1	1	1
Cars, push	1	1	1
Chisels, track	6	6	12
Cups, tin	2	2	4
Drills, ratchet, 3 bits	1	1	1
Files	1	1	1
Funnels, for filling oil cups	1	1	1
Grindstones, complete	1	1	1
Gage, track	1	1	2
Handles, extra, for adz	2	3	4
Handles, extra, for ax	1	1	1
Handles, extra, for sledge and spike-mauls	3	4	6
Hatchet, with handle	1	1	1
Hoes, scuffle (gravel ballast only)	4	6	10
Hooks, brush	1	1	2
Jacks, track	1	1	2
Kegs, water, 10-gal	1	1	1
Lanterns, complete; red, green, white, yellow, of each color	2	2	2
Lantern globes, extra of each color	1	1	1
Levels, track	1	1	1
Lines for ditching, 100-ft	1	1	2
Mattocks	1	1	1
Mauls, spike, with handles	4	4	6
Picks, clay, (not needed with tamping-picks)	3	4	6
Picks, tamping (not needed with tamping-bars)	4	5	9
Pliers, wire	1	1	1
Punch, track, with handle	1	1	1
Rakes	1	1	1
Saws, hand	1	1	1
Scythes, grass, complete	4	6	8
Shovels, track	5	7	12
Signal flags; red, yellow, green, each color	4	4	4
Sledge, with handle, 10- to 14-lb	1	1	1
Spike-puller	1	1	1
Tape line, 50-ft	1	1	1
Tongs, tie (when ties are treated)	2	2	4
Torches	2	3	4
Torpedoes	12	12	12
Whetstones	3	4	6
Wire-stretchers	1	1	1
Wrenches, monkey	1	1	1
Wrenches, track	4	6	6
Wire, telegraph, 100-ft. coil	1	1	1

provides three primary accounts for the machines, tools, and supplies used directly and indirectly by the maintenance of way department. Two of these, *Roadway Machines* and *Small Tools and Supplies*, are under the general account *Maintenance of Way and Structures* and the third, *Work Equipment*, is under the general account *Maintenance of Equipment*. The account *Small Tools and Supplies* is subdivided into *Roadway and Track Tools*, and *Roadway and Track Supplies*.

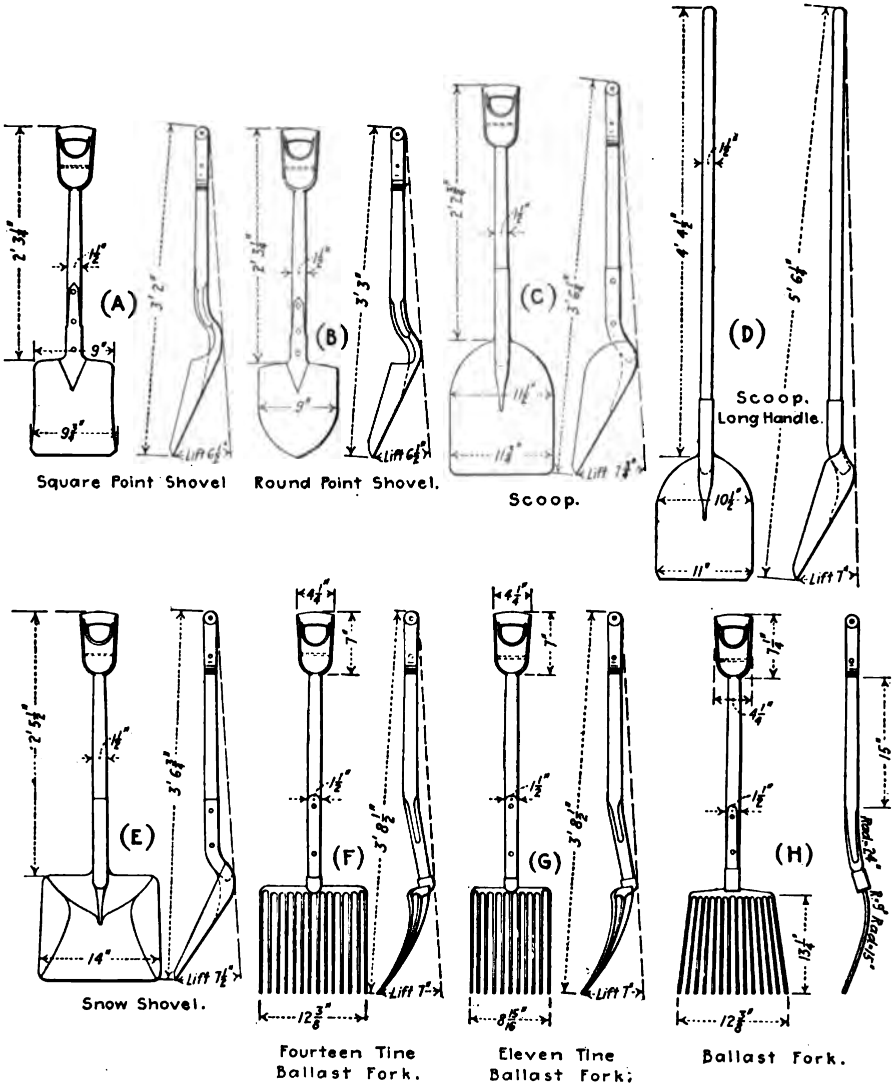
The most important tools and supplies are included in the list referred to in the following article and are described in Arts. 251 to 257. Roadway machines and work equipment are described in Arts. 258 to 262.

250. Tools for the Section-gang.—Each section should have a full equipment of first-class standard tools sufficient to supply every man in the gang, and several extra tools to replace those which break or which must be sent to the shop to be sharpened or repaired. The actual equipment will vary somewhat, according to the kind of ballast and the general character of the track. The list given in Table 23 is representative of the average equipment for gangs composed of foreman and 3, 5, and 10 men.

In addition to the equipment given in the table each roadmaster should carry on hand the following tools for use on the various sections as required: 1 rail-bender; 2 track-drills, and 4 extra bits for each size of drilling; 2 18-in. hack-saw frames; 2 doz. hack-saw blades; 4 track-jacks; 2 cross-cut saws; 6 rail tongs; 2 rail-forks; 30 scoop-shovels; 12 wheelbarrows.

251. Tools for Handling Ballast and Earth.—Five types of shovels are shown in Fig. 187, (*A*) to (*E*). The square-point shovel is the most serviceable for general track work and is the only form that can be used for tamping. The round-point shovel is preferable for digging. Forks for handling stone or coarse slag ballast are shown at (*F*), (*G*), and (*H*).

Three forms of tamping-bars are shown at (*A*), (*B*), and (*C*), Fig. 188. Ordinarily the handle is a piece of round iron from ¾ to 1 in. in diameter, but the bar shown at (*A*) has a hollow handle made from a piece of gas-pipe. Thus a larger handle is obtained which offers a better grip for the hand without increasing the weight. Bars (*B*) and (*C*) have a chisel edge at the top of the handle and when reversed can be used as lining- or pinch-bars. The length of the tamping-face is from 3 to 4 in. and the width from ⅜ to ¾ in. The working ends should be made of hard steel. Many trackmen prefer the tamping-pick to the tamping-bar. The tamping-pick differs from the ordinary clay-pick only in having one end widened to form a tamping-face similar to that of the tamping-bar. The other end is pointed. Two forms of tamping-picks are shown at (*D*) and (*E*). Tamping-picks can be used for all but earth ballast. A pick usually has a tapered eye for the straight handle, as at (*D*) and (*F*). The eyeless pick, (*E*), has a socket at the middle to receive the end of the handle, which is held in place by a bolt passing through the handle and the sides of the socket. This pick weighs 7⅛ lb. without the handle. A common pick or clay-pick, (*F*), usually has one pointed end and one end with a chisel edge, though picks with both ends pointed are used also. The length of both tamping- and clay-picks is from 24 to 27 in., and the weight is



Square Point Shovel Round Point Shovel. Scoop.

Snow Shovel. Fourteen Tine Ballast Fork. Eleven Tine Ballast Fork; Ballast Fork.

FIG. 187.—Shovels and ballast-forks.

from 6½ to 8 lb. Sometimes the tamping-arm of the pick is made 1½ in. shorter than the pointed arm. The picks of the Pennsylvania Railroad are made of open-hearth steel having from 0.55 per cent. to 0.75 per cent. carbon, not over 0.04 per cent. each of phosphorus and sulphur, and about

0.40 per cent. manganese. A standard form of grub-hoe is shown at (*G*). Its weight is 18⅝ lb. without the handle.

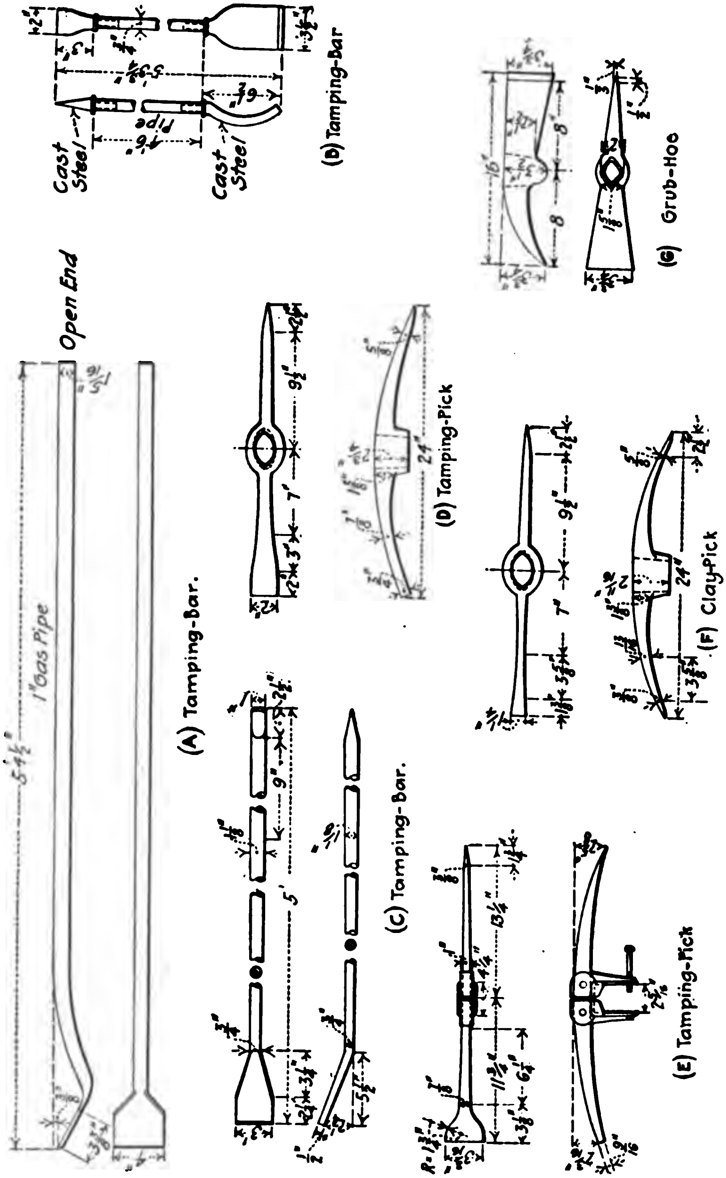


FIG. 188.—Picks and tamping-bars.

Ballast-templates or ballast-shoulder boards are used as a guide in maintaining the ballast shoulder to the standard section. Two forms are shown in Fig. 189. That shown at (*A*) is constructed of wood and is attached to a heavy timber which extends across the rails and is notched to receive each rail-head. Thus the template is held at the proper distance from the rail. That shown at (*B*) is made of metal and the tapered end fits over the outer flange of the rail-base and against the rail-web.

Figure 190 shows a device for marking the sod line beyond the toe of the ballast. It consists of a horizontal arm and brace, temporarily attached to a hand- or push-car, and two levers attached to the end of the arm and extending parallel to the track. The end of one lever carries a knife-edge and wing for cutting the sod and turning a small furrow. The relative position of the two levers is regulated by means of a set screw on one lever engaging an arc attached to the other lever. When not in use the levers can be folded together. A man walking beside the track bears down on the upper lever, forcing the knife-edge into the sod.

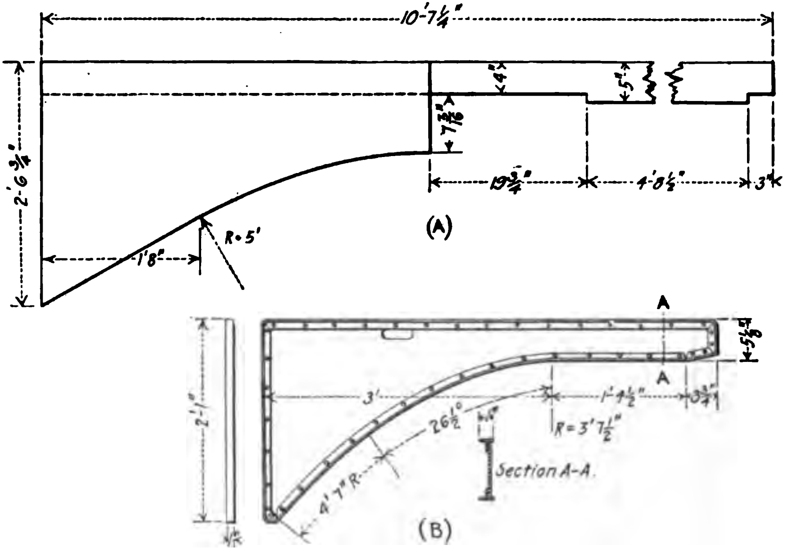


FIG. 189.—Ballast-templates.

252. Tools for Handling Ties.—Two forms of adzes used for adzing ties and timbers are shown at (*A*) and (*B*), Fig. 192. The weight of (*A*) is 4½ lb. A hand-machine and template used by the Delaware, Lackawanna and Western for boring ties for screw-spikes is shown in Fig. 191. The boring-machine is mounted on a light frame about 2 ft. 4 in. long by about 7½ in. wide. The template consists of an angle-bar to which are riveted two flat plates spaced in accordance with the dimensions of a tie-plate to be used with a given rail section and punched according to the arrangement and size of spikes. One end of the angle-bar is hooked to fit over one end of the tie. When a tie is to be bored the template is laid on the tie with the hooked end tight against one end of the tie, the punch shown in the illustration is inserted successively in each hole of the template and struck with a hammer, and, after the template is removed, the bit of the boring-machine is started in a hole thus marked. The template shown is for 8-ft. 6-in. ties. When an 8-ft. tie is being bored a 3-in. block is inserted between the hooked end of the template and the end of the tie.

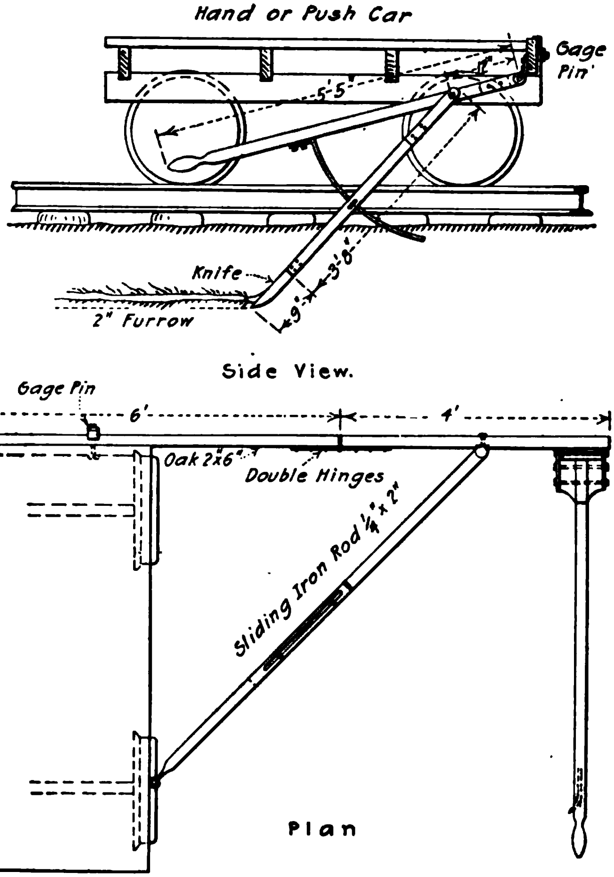
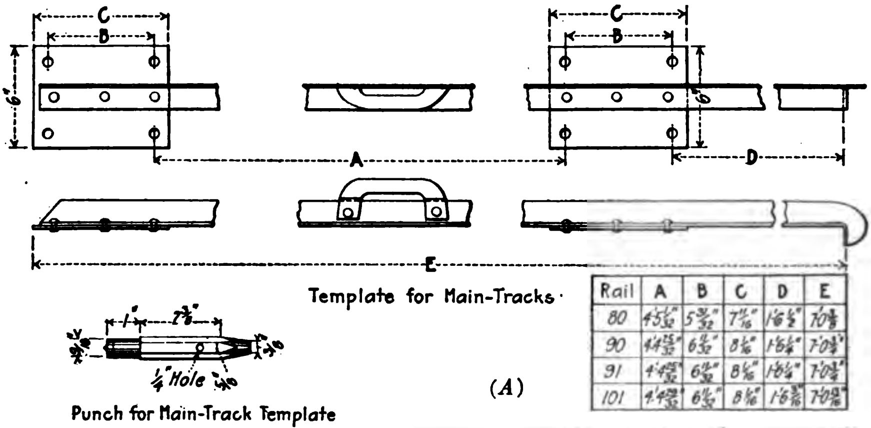


FIG. 190.—Sod-line marker.

Treated ties should be handled only with tie tongs because of the danger of poisoning. A common form of tie tong is shown at (*C*), Fig. 192. Its weight is from 9 to 11 lb. When the tongs are being used one man holds each handle. Also tongs of this kind are very useful for handling large switch- or bridge-timbers. A less common form is shown at (*D*).

253. Tools for Handling Rails.—Two forms of tongs used for handling rails are shown at (*E*) and (*F*), Fig. 192. The jaws are smaller than those of tie tongs and fit over the rail-head, as shown at (*E*). This tong has unusually long handles and weighs 23 lb. Rails also may be handled with rail-forks (*G*). The fork is from 2 ft. 6 in. to 3 ft. long and has a slot about ¾ in. wide and from 4 to 8¼ in. long. The fork in the figure weighs about 13 lb. The slot slips over the rail-flange, which is gripped by the fork when the end of the handle is raised.

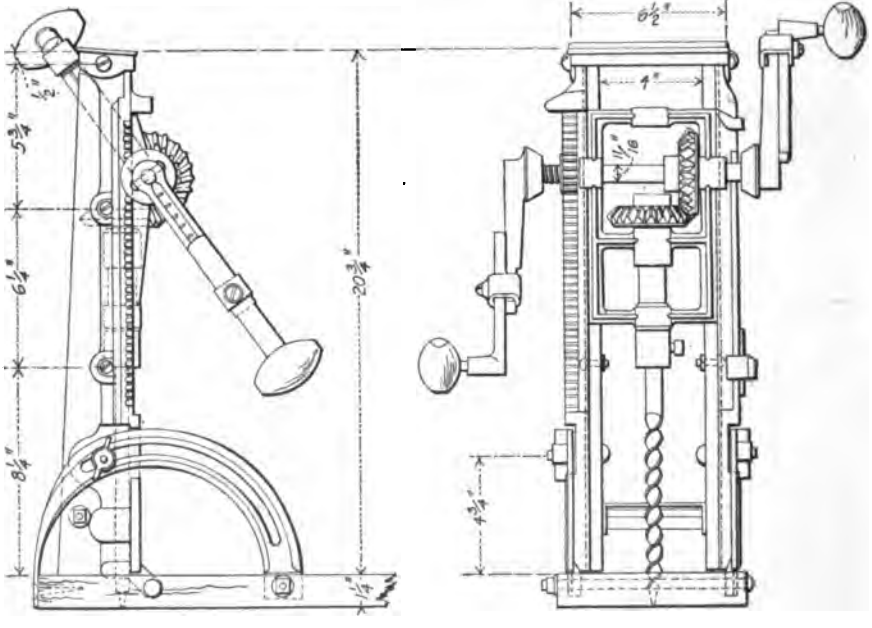


Template for Main-Tracks

Punch for Main-Track Template

(*A*)

Rail	A	B	C	D	E
80	4' 5 1/32"	5 31/32"	7 11/16"	1' 6 1/2"	7' 0 1/8"
90	4' 4 25/32"	6 11/32"	8 1/16"	1' 6 1/4"	7' 0 3/4"
91	4' 4 25/32"	6 11/32"	8 1/16"	1' 6 1/4"	7' 0 3/4"
101	4' 4 23/32"	6 5/32"	8 1/16"	1' 5 31/32"	7' 0 15/16"



(*B*) Tie-Boring Machine

FIG. 191.—Tie-boring machine and template.

Rail-benders are used to bend rails for curves and to straighten curved or kinked rails. Two forms of portable benders are shown at (*A*) and (*B*), Fig. 193. The Jim Crow bender, (*A*), consists of a steel yoke, the ends of the two arms of which are hooked to engage one side of the rail-head. The leverage for bending the rail is applied through a screw which engages the opposite side of the rail-head between the arms of the yoke. The fulcrum of the Superior bender, (*B*), is in the middle and the leverage

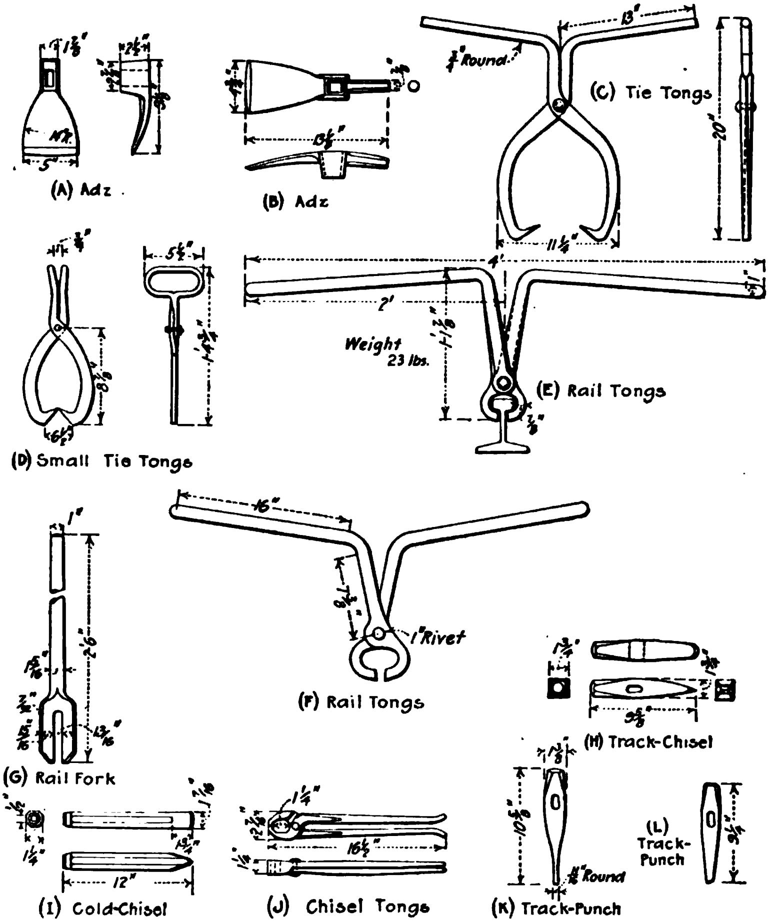
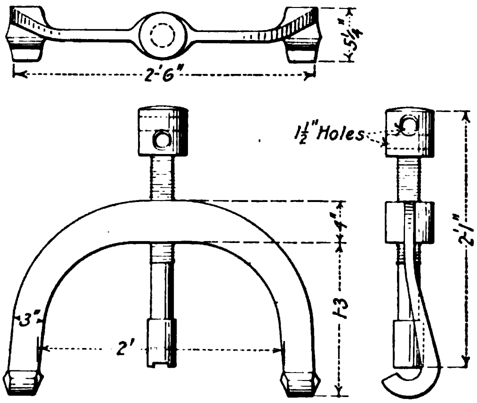


FIG. 192.—Tools for handling ties and rails.

is applied through a screw at the end. The principle of the Sampson bender is the same as that of the Superior. Portable benders are very useful for ordinary track work, but it is difficult to bend the rails uniformly with them. Bending twenty rails a day is a good day's work for six men with one bender. When a large number of rails must be bent, the work should be done by a power-bender which may be mounted on a special car or installed in the general shops. A simple form of power-operated bender, which should be classed as a Roadway Machine, used by the Baltimore and Ohio Railroad is shown at (*C*). It consists of a semicircular steel yoke, a steel strap connecting the ends of the yoke, and an adjustable rod between the yoke and strap. The curving is done by three wheels 10 in. in diameter, one mounted on the adjustable rod and one at each intersection of the strap and yoke. The spacing of the jaws is 4 ft. The



(A) Jim Crow

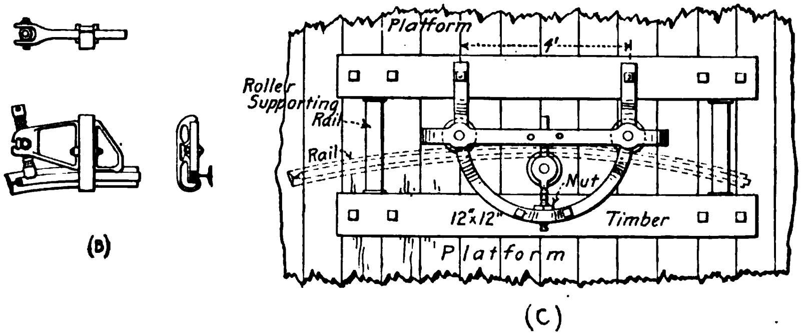


FIG. 193.—Rail-benders.

device is rigidly bolted to a platform or to the top of a flat car, and the curving is done by attaching a cable from a locomotive or stationary engine to one end of the rail and pulling the rail between the three wheels. The cost of bending by this method is about 20 cts. per 33-ft. rail. Also a roller bender is manufactured which is operated by hand. After the bender is applied to the rail and set to the desired curve a socket wrench is placed on a pin in the central roller, and, by turning the wrench, the bender is made to roll along the rail. Bending with a sledge or by dropping the rail should never be allowed.

Rails may be cut by means of chisels or saws. Chisels should be used only in emergencies as the cut is very uneven and the work is dangerous to the men doing the cutting. A hack-saw may be used, but a portable circular saw, Fig. 194, is the most satisfactory hand-operated saw. The machine rests on and is clamped to the rail and is braced by a leg on each side of the rail. Two men are required to turn the cranks. An automatic feed lowers the saw at the proper speed for cutting the head and base of the rail. A greater speed can be obtained through the web by feeding the saw by hand.

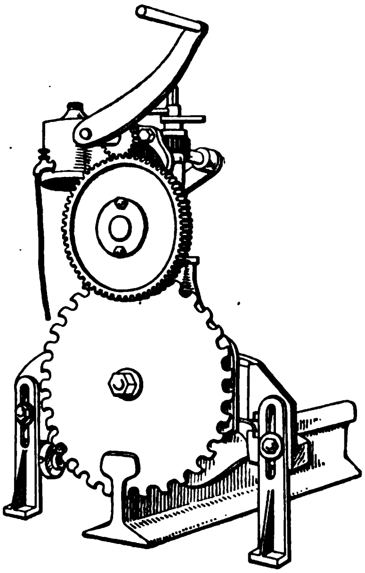


Fig. 194.—Portable rail-saw.

Figure 192 shows a track-chisel or rail-cutter (*H*), a cold-chisel (*I*), and tongs, (*J*) for holding the cold-chisel. Track-chisels are held by a wooden handle inserted in the eye. The track-chisel shown weighs 6 lb. After one chisel has been used to cut three or four rails it must be sent to the shop to be sharpened and retempered. The standard track-chisel and track-punch of the Pennsylvania Railroad are made of crucible steel of 0.80 per cent. to 0.90 per cent. carbon, not over 0.04 per cent. each of phos-

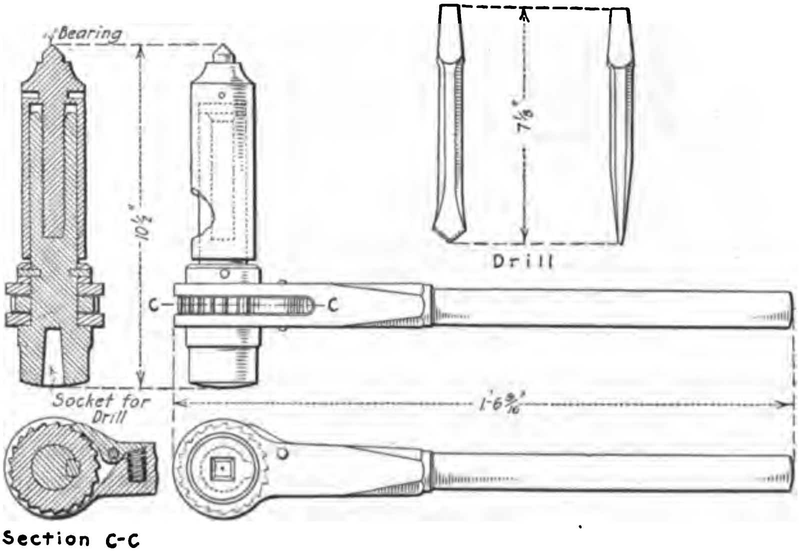


Fig. 195.—Hand ratchet-drill.

phorus and sulphur, and 0.30 per cent. to 0.35 per cent. manganese. Two forms of track-drills used for drilling bolt-holes or holes for bond-wires are shown in Figs. 195 and 196. The hand ratchet-drill, Fig. 195, is handy for occasional drilling, but is uneconomical when many rails must be drilled. It is held by a frame, not shown in the figure, which hooks under the rail-base. The frame should be arranged so that the drill can slide along it, and should be of such length that all holes at a rail-joint can be drilled without shifting the frame. The most efficient form of hand track-drill is one driven by cranks mounted on a vertical frame. A drill of this type, known as the Type-A New Style Paulus track-drill, is shown in Fig. 196. The drill is driven by beveled gearing from a vertical shaft. The vertical shaft is driven by beveled gearing from a double crank. The lengths of the crank levers are adjustable. The drill is fed automatically and a handle at the back of the horizontal frame is used to return the drill quickly. Hydraulic punches, screws, and hand-punches are used occasionally for making holes in rails. A round and a square hand-punch are shown at (K) and (L), Fig. 192. The square punch, (L), weighs 5 lb. It differs somewhat from the ordinary punch, as the punching

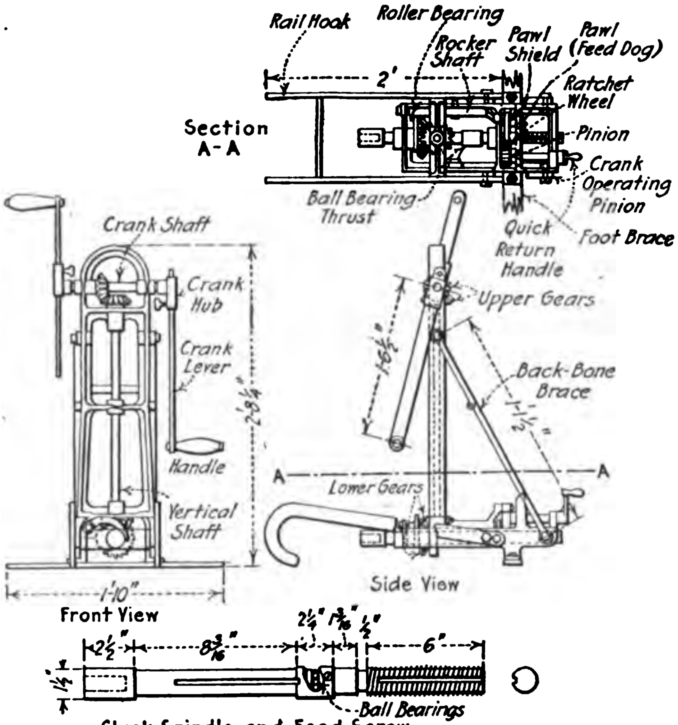


FIG. 196.—Type-A new style Paulus track-drill.

surface is beveled. Hand-punches are fitted with handles similarly to track-chisels.

254. Tools for Handling Track and Track Fastenings.—The different kinds of hammers used in track work are shown in Fig. 197. Striking-hammers or sledges, (*A*) and (*B*), usually weigh 8, 10, or 12 lb. They are double-faced and the faces are either circular or octagonal. They are used for striking chisels, punches, etc. If the striking-face is allowed to become rough there is danger of pieces chipping off and striking the workmen.

Spike-mauls, (*C*) to (*E*), Fig. 197, are used for driving track-spikes. Usually their weight is 10 lb., though 8-lb. mauls are used occasionally. The length of the head is from 12 to 15¼ in. The striking-faces are round. Both may have the same diameter or the diameter of one may be made ⅜ or ½ in. less than the other for use where space is limited.

A track-walker's hammer, (*F*), Fig. 197, has a head from 4 to 5 in. long. The other end is curved and is brought to an edge or a point. The hammer shown weighs 7 lb. A bridge-inspector's hammer is shown at (*G*); (*H*) is a ballast- or knapping-hammer for breaking stone ballast; (*I*) is a stone-sledge; and (*J*) is a tie-plate swage, used for driving down and seating tie-plates. The swage weighs 13 lb.

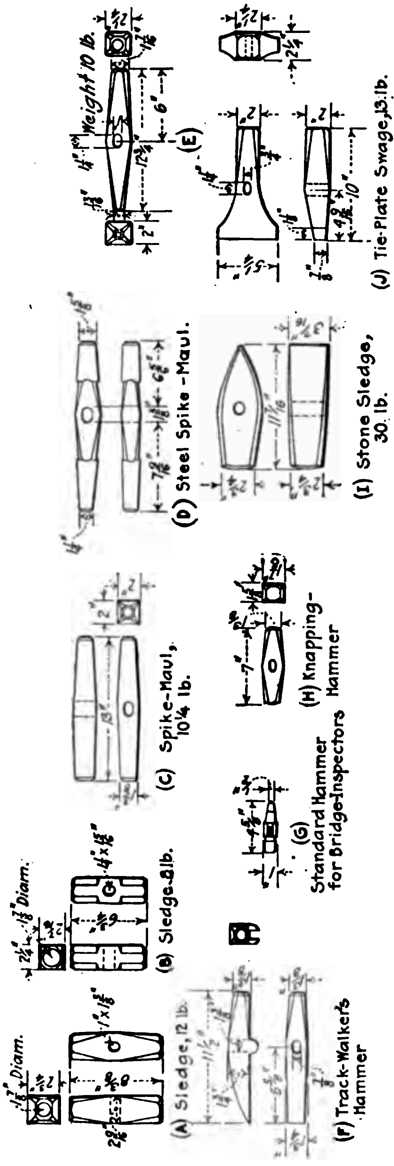


FIG. 197.—Hammers.

A lining-bar, (*A*) to (*D*), Fig. 198, is a straight bar 5 or 5½ ft. long used for throwing and lining track. The bar may have a wedge point, (*A*), diamond point, (*B*) and (*C*), or chisel point, (*D*). The bar is 1¼ to 1½ in. square at the point and tapers to a round bar about ¾ or ⅞ in. in diameter at the other end. A pinch-bar is used for prying up track at low joints while the joints are being tamped; to hold up a tie

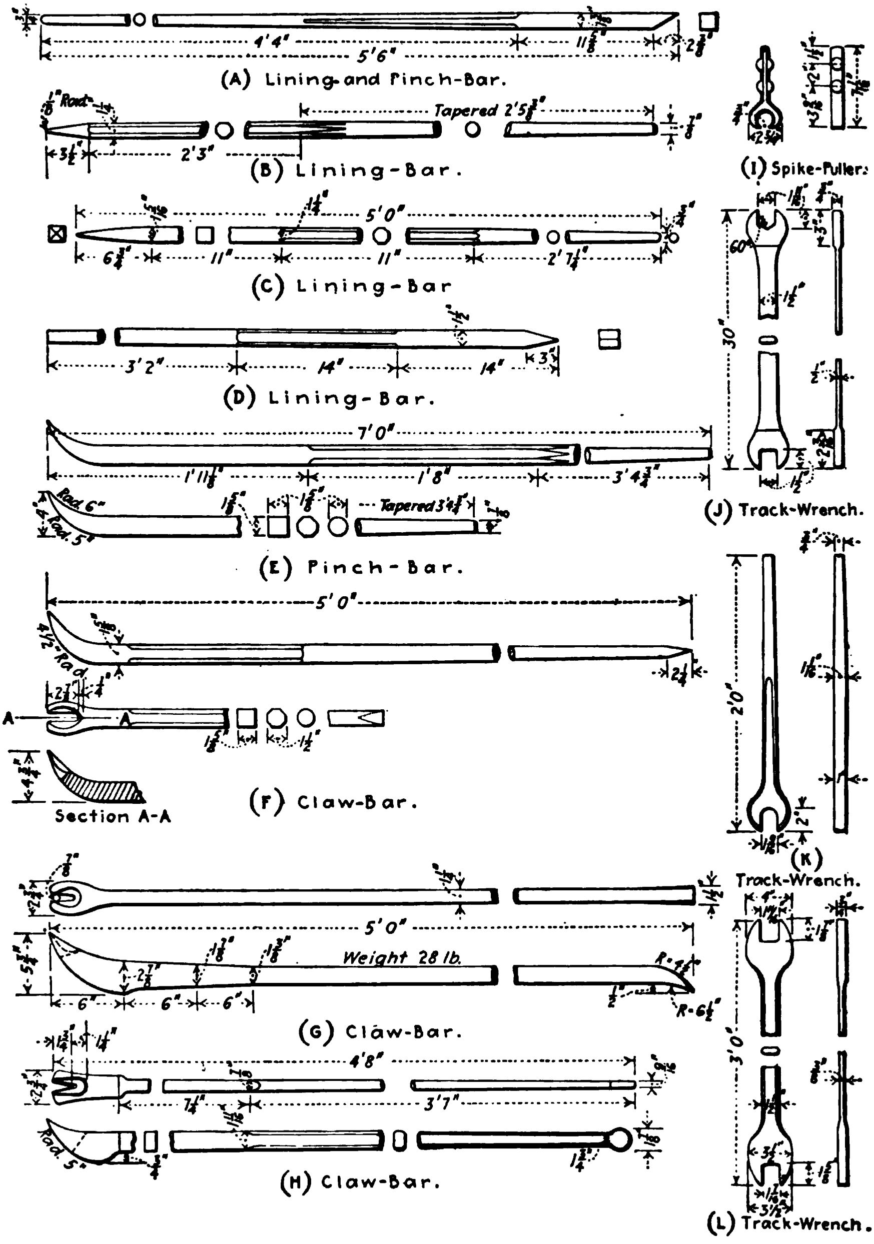


FIG. 198.—Bars and wrenches.

while it is being spiked; and occasionally for light raises of track during ordinary surfacing. The bar shown at (*A*) is used quite extensively, but a bar having the end slightly turned up, as at (*E*), is more satisfactory. Bar (*A*) weighs 24 lb.

A claw-bar has a bent, forked end and is used for drawing spikes, either direct or with a spike-puller. The usual length is 5 ft. Three forms are shown in Fig. 198, (*F*) to (*H*). The foot of the bar may be plain, (*F*), or may have a heel (*G*) and (*H*). The heel acts as a fulcrum. The upper ends of bars (*F*) and (*G*) are brought to a chisel edge. When the bars are reversed (*F*) becomes a lining-bar and (*G*) becomes a pinch-bar. Bar (*G*) weighs 28 lb.

A spike-puller, (*I*), Fig. 198, is used with a claw-bar for pulling spikes on the inside of guard-rails and at frogs, switches, and other points where there is insufficient room to use the ordinary claw-bar. To pull a spike, the jaws of the spike-puller are slipped under the head of the spike and the jaws of the claw-bar are slipped under one pair of lugs on the shank of the puller, the heel of the claw-bar resting on the head of the rail.

The usual form of track-wrench, used for tightening bolts at rail-joints, is a flat or round steel bar from 24 to 36 in. long, having jaws either on one end or on both ends. The end of the slot may be semicircular, square, or two-sided to fit a hexagonal nut. Three forms of track-wrenches are shown in Fig. 198, (*J*) to (*L*). The two shown at (*J*) and (*L*) are double-ended wrenches and have flat handles. The end of one of the slots of (*J*) is two-sided to fit a hexagonal nut; (*K*) is single-ended and has a round handle. These wrenches are intended for use with ¾- to 1-in. bolts, and are made of open-hearth steel with 0.40 per cent. to 0.55 per cent. carbon. The jaws of a wrench should be hardened to such an extent that a new file will not cut into the sides of the jaws. A double-ended wrench with an S-shaped handle is used by a few railways. Wrenches with handles longer than 30 in. allow so great a leverage that care must be taken when tightening a bolt to prevent stripping the threads or bursting the nut. Track-wrenches weigh from 6 to 10 lb. The weight of (*K*) is 7 lb. and that of (*L*) is 9.15 lb.

The capacity of jacks used in track work ranges from 5 to 20 tons. Heavier jacks are required for bridge work, the capacity ranging from 25 to 75 tons. For ordinary track work the capacity need not exceed 10 tons. Jacks of high capacity usually are operated by ratchets, while those of low capacity may be operated by screws or friction clutches. Ratchet-jacks may be single acting, in which the jack operates only on the downward stroke of the lever, or double acting, in which the jack operates both on upward and downward strokes. They may be lowered by similar strokes, the direction of movement being reversed by an eccentric, or they may be provided with an automatic trip which allows the load instantly to fall by releasing the palls. The double-acting ratchet trip-jack is the most useful for general track work, as the load can be quickly raised, and instantly released on the approach of a train. The jack is operated with a wooden handle inserted in the lever socket. A trip-jack must be carefully handled to prevent accidental tripping. Fig. 199 shows a jack of this type. The lift of jacks varies from 10 to 20 in., 13 or 13½ in. being the lift of the usual track-jack of 10 tons capacity. When it is desired to lift the track the ballast is partly dug out from under the rail between two ties to give a bearing for the foot of the jack, the jack is set outside the rail with the lifting-arm under the rail-base, and the track is lifted by pumping up the jack.

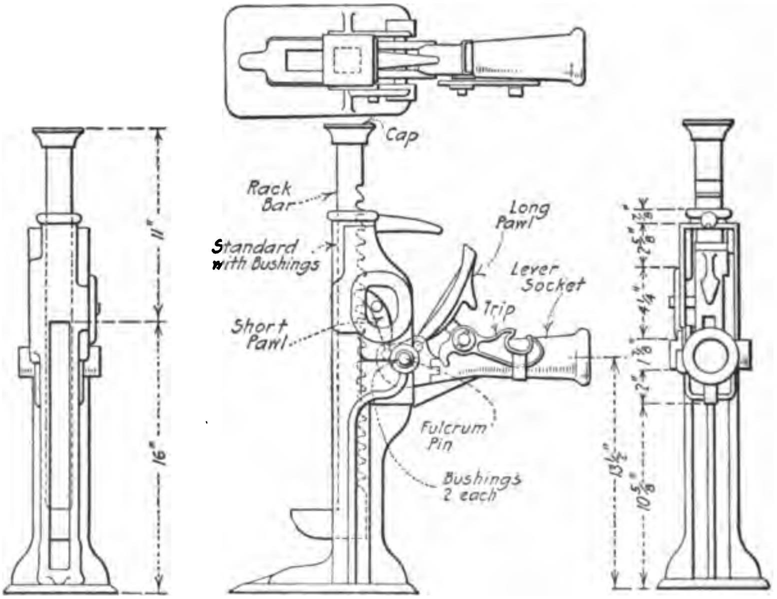


FIG. 199.—Barrett track-jack.

255. Track-gages and Track-levels.—A track-gage is a device used as a guide for laying rail to proper gage and to test the gage of existing track. It consists of a metal or wooden bar with plain, forked, or tee ends. The gage is given by fixed lugs on each end of the bar, the distance between outer faces of lugs being 4 ft. 8½ in. for standard gage on tangents. The length of the track-gage is such that it rests on the tops of the rails, the lugs projecting downward inside each rail. A base-gage is used in some cases. This rests on the tops of the rail-flanges and the lugs project downward inside the flanges. Track-gages are made in a variety of forms, four of which are shown in Fig. 200. The gage shown at (*A*) is used by the Baltimore and Ohio Railroad. At each end it has a vertical gage-plate 7³⁄₁₆ in. long, curved to a radius of 2 ft. 4¼ in. The curve insures an accurate indication of the gage of rails even if the track-gage is not exactly perpendicular to the track. Gage (*C*) is equipped with similar curved plates. One end of gage (*D*) is forked, each arm having a lug. If

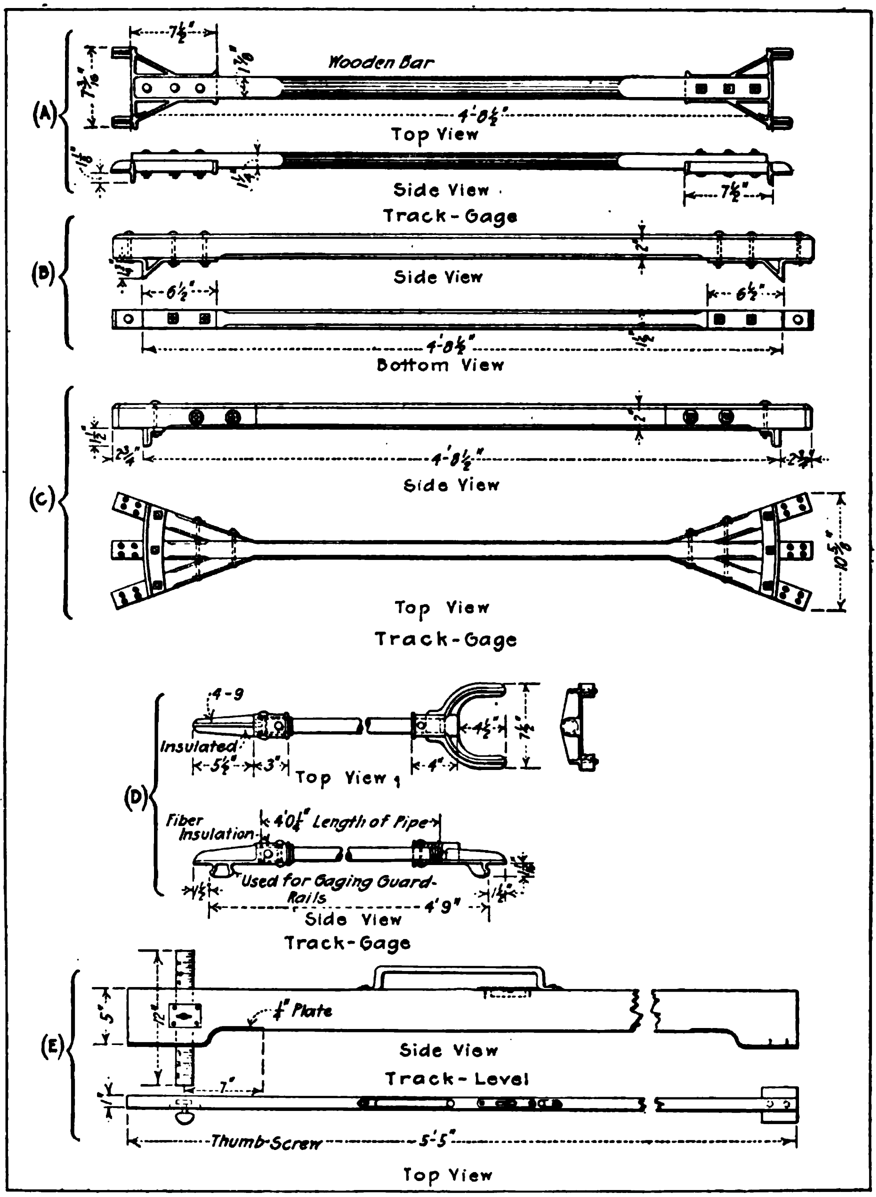


FIG. 200.—Track-gages and track-levels.

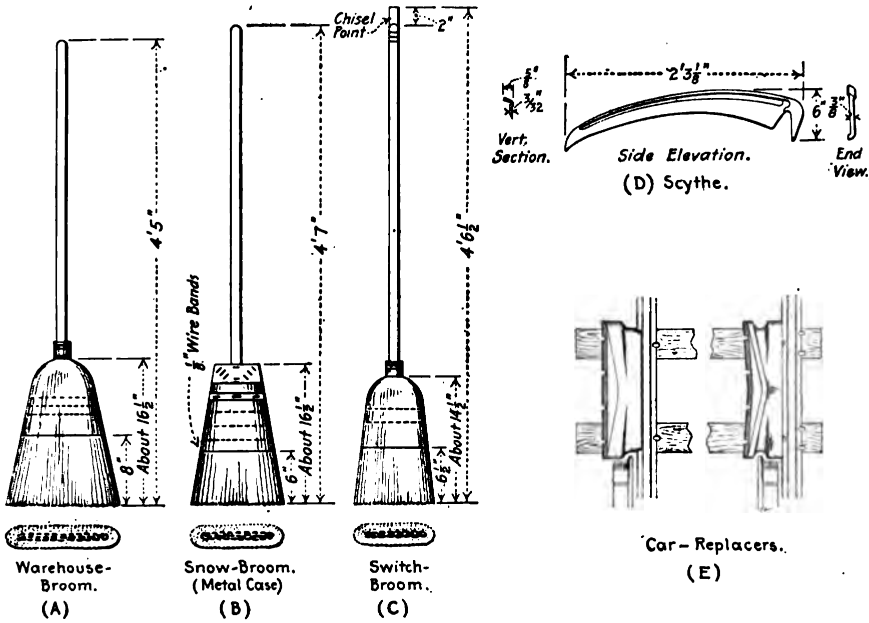
this gage is not set perpendicular to the track the fact will be apparent by one lug not being in contact with the side of the rail-head. The body of this gage is an iron pipe and the fork and tip are malleable iron. A hard fiber thimble is inserted between the tip and the pipe as an insulation so that the gage can be used on track carrying electric circuits. If the body of the gage is wood no other insulation is necessary. Track-gage (*D*) has a gage of 4 ft. 9 in. and is used by the Southern Railway on curves of 4° or over. The gage-lug on the tip is finished on both inner and outer surfaces. The inner surface is used for gaging guard-rails.

The length and shape of the lugs of a track-gage must be such that the lugs will not catch on splice-bars at joints. Track-gages should be tested frequently by the roadmaster. The tee or forked end must be square with the center line of the gage, the bar straight, and the ends firmly fastened to the bar. Only insulated gages should be used on track carrying signal circuits.

A track-level, (*E*), Fig. 200, is used to test the difference in elevation of the two rails. On tangents this should be zero. On curves it should be the amount of the practical superelevation. A track-level consists of a wooden board from 5 ft. 5 in. to 5 ft. 8½ in. long, with a spirit level set into the top near the center. The bubble-tube should be provided with an adjusting screw. The under side of the board should be shod with metal at each bearing on the rail. The bubble must be adjusted to read zero when the two bearing surfaces of the board are in the same horizontal plane. The adjustment of the bubble is tested by turning the board end for end, that is, reversing it 180°. The reading of the bubble should be the same in both positions of the board. The amount of superelevation is found by means of a graduated metal scale sliding in a vertical hole over one bearing surface. A thumb-screw is used to set the scale at any graduation. The scale may be graduated to read on a level with either the top or the bottom of the board. The scale of the level shown in Fig. 200 is read at the bottom of the board. For the other method of graduation the zero of the scale must be a distance above the bottom of the scale equal to the thickness of the board. Track-levels should be tested frequently. The sensitiveness of the bubble should be such that a difference of ⅛ in. in elevation of the two rails can be detected. Sluggish bubble-tubes should be replaced.

Sometimes a combination gage and level is used. This has a bubble-tube mounted on an ordinary track-gage to which the sliding scale is attached. Another form of track-level consists of a level-board with one end cut in a series of steps of known height. The steps are used to find the difference in elevation of the two rails.

256. Miscellaneous Tools.—Three kinds of brooms are shown in Fig. 201, (*A*) to (*C*). The warehouse- and snow-brooms, (*A*) and (*B*), are made of broom-corn with a center filler of split bamboo or split rattan. These brooms weigh about 3 lb. each. The switch-broom, (*C*), is made of rattan and weighs 2½ lb. It has a chisel-edged metal tip at the end of the handle for cleaning dirt and ice from switches and flangeways. Also snow-brooms may be equipped with the metal tip. Any of the brooms may be made with a metal case, as at (*B*).



Warehouse-Broom. (A)

Snow-Broom. (Metal Case) (B)

Switch-Broom. (C)

FIG. 201.—Miscellaneous tools.

The standard blade of a scythe used for mowing the right-of-way is shown at (*D*). A pair of car-replacers or rerailers are shown at (*E*). Though not a track tool, employees of the maintenance of way department occasionally are called upon to use them. They are used to replace

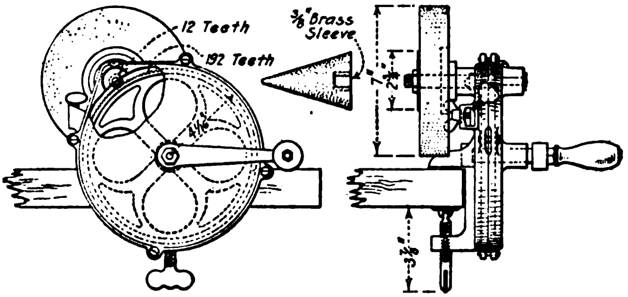


FIG. 202.—Keystone tool-grinder.

derailed wheels upon the rails. They consist of hollow, reinforced castings with inclined planes and diagonal grooves, surfaces, or ridges which, by engaging the flanges of the wheels, lift the wheels above the rails, at the same time crowding them back upon the rails. Rerailers should be provided with sharp calks for holding them to the ties, and also should have holes or slots for spikes. One form has a hooked arm which extends under the rail and hooks over the opposite side of the rail-base. This prevents any lateral movement of the rerailers as the wheels mount them. The rerailers shown weigh 184 lb. per pair.

A tool-grinder, used to sharpen tools which do not need to go to the shop, is shown in Fig. 202. A two-wheeled track-dolly, used by bridge-gangs for moving heavy timbers, etc., is shown in Fig. 203. This rides on one rail and is prevented from overturning by placing the timber on it transversely and having the timber held approximately horizontal by men walking at the side.

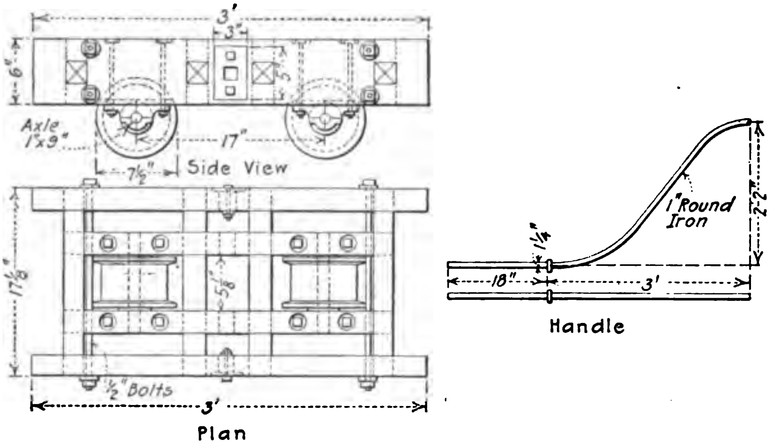


FIG. 203.—Track-dolly.

257. Roadway and Track Supplies.—These are the various supplies consumed in connection with the operation of roadway machines while used in repairs of roadway and track; the supplies used by track-walkers and track-watchmen; and the supplies used in the general repair and maintenance of roadway and track. They include alcohol for hydraulic jacks and for cleaning lenses and glasses of switch- and signal-lamps; fuel for heating maintenance of way buildings; fuel for portable forges used in track work; gasoline for motor-cars; oil and waste for hand-cars, etc.; supplies used for lighting maintenance of way buildings; salt for switches; ice and water for maintenance of way buildings; and torpedoes used by track-walkers and section forces.

258. Roadway Machines.—The following are the most important roadway machines: portable boilers; hand-, push-, and motor-cars; pneumatic machines; concrete-mixers; dredging-machines; grading-outfits; hydraulic jacks; land and skid pile-drivers; unloading-plows; hand rail-unloaders; rock-crushers; steam-rollers; and track-velocipedes. Machines under this heading must not be permanently mounted on railway-cars or on floating equipment. As the larger machines usually are so mounted a description of them is given in Art. 261, "Work Equipment."

A pneumatic tie-tamping machine has been tried recently with good results. The tamper is operated with compressed air from a compressor connected to a gasoline engine. The compressor and engine are of such size that they can be mounted on an ordinary track motor-car. The tamper is about 4 ft. long and is vibrated the same as any ordinary pneumatic hammer. It has two hand-grips and when being used is held by one man. One small compressor will feed two tampers. The tamping-foot is similar to that of a tamping-bar. Tests of the device on the New York Central and Hudson River Railroad indicate that the ballast is tamped firmer and more uniformly by the pneumatic tamper than can be done by hand with a tamping-bar.

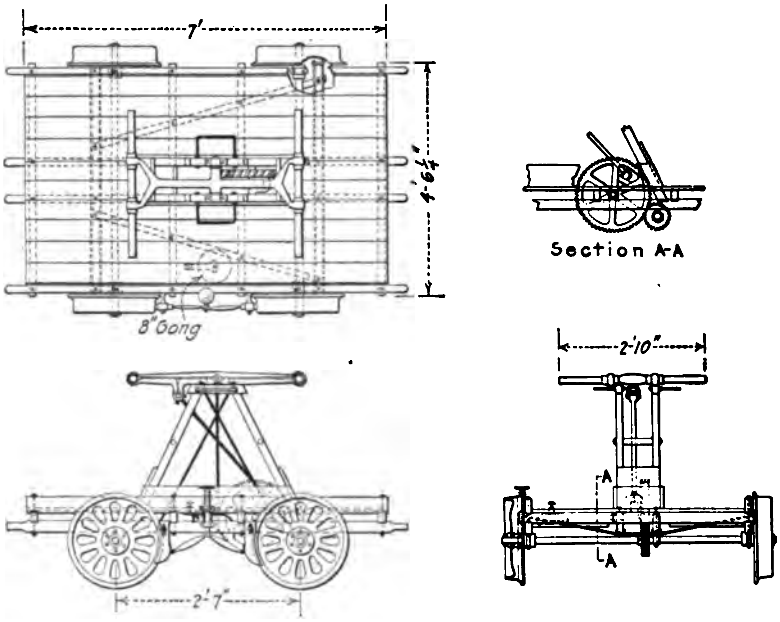


FIG. 204.—Hand-car.

259. Hand-cars, Hand-velocipedes and Push-cars.—Prior to the development of the gasoline engine all section- and inspection-cars and velocipedes were propelled by hand. Hand-cars are used particularly to transport the sectionmen and their tools, supplies, and small material to and from the place of work. A hand-car is driven by a lever pivoted at the middle and connected about midway between the pivot and one end to a driving-rod. The lower end of the driving-rod is connected to a crank on the spur-wheel which gears with a pinion on one axle of the car.

The lever has a cross-handle at each end and can be worked by four men. The car must be equipped with strong brakes, which usually are worked by a treadle. A gong, also operated by a treadle, should be attached under the car and should be sounded when approaching crossings. The car should be inspected once a week and the parts kept thoroughly lubricated. The details of a standard hand-car are shown in Fig. 204. The weight of section hand-cars is about 500 lb. Larger cars are required for bridge-gangs. These weigh from 650 to 750 lb. The car should have four handles at each end of the body to be used by four men when the car is lifted on and off the track. The handles of the lever should be made of hickory and the floor and frame of the car of white oak. The wheels may be pressed steel or may have steel tires and wooden centers. Steel wheels must be insulated if the track carries signal circuits. Sometimes a tool chest is placed under the car. If placed on the car it can be used as a seat. Regular seats along the sides of the car are provided occasionally. The gears vary from about 3 to 1 to 4 to 1. Low gears are necessary where the gradients are steep.

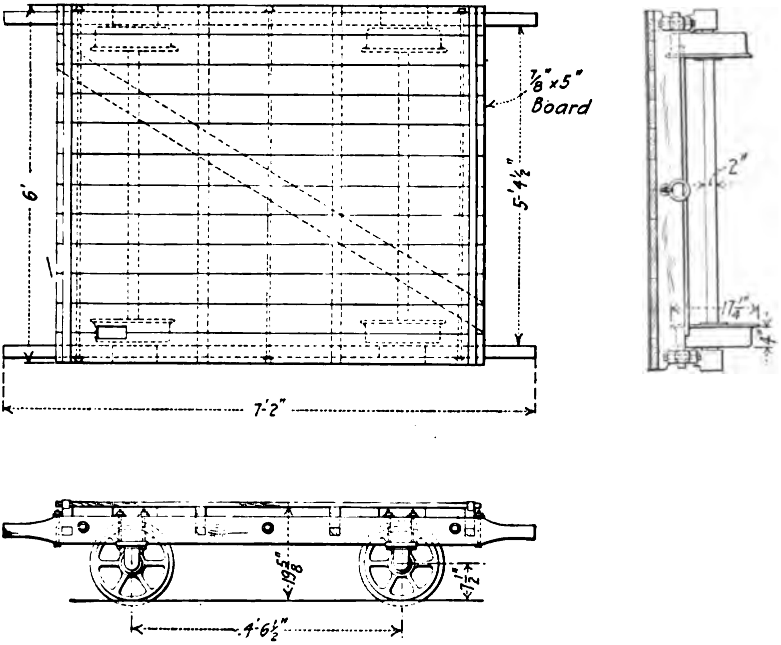


Fig. 205.—Push-car.

A push-car has neither propulsion mechanism nor brake-gear and must be pushed or trailed along the track. Push-cars are used for moving earth, ballast, stones, ties, tools, etc. The push-car shown in Fig. 205

has bearings outside the wheels. This provides greater stability when heavy material is being handled over the side of the car.

A track-velocipede consists of a light frame mounted over two wheels which run on the same rail, and an outrigger carrying one wheel which runs on the other rail. The operator sits astride the frame and propels the car by means of an upright lever with or without treadles. An additional seat may be provided so that the velocipede will carry two persons. The car may be arranged also to carry a small tray of tools and supplies. Track-velocipedes are used exclusively for purposes of inspection and patrol. They must be light enough to be lifted by one person.

An inspection hand-car is a light four-wheeled car with a seat for two or three persons placed across the front of the car, facing the track. A brake-lever is placed in front of the seat so that the inspector can stop the car at will. The car is operated by two or four men who stand back of the seat. These cars weigh from 450 to 500 lb.

260. Motor-cars for Maintenance Work.—During the past few years there has been a rapid increase in the use of gasoline motor-cars in maintenance work. These were used first as inspection-cars. The advantages to be gained by substituting the motor-car for the hand-car and -velocipede are so numerous that it is only a matter of a few years until the hand-car will disappear from the equipment of most railways. Briefly, the advantages are as follows: (1) The time spent in going to and from work is reduced and the length of the working-day is correspondingly increased. (2) The length of the section and the size of the section-gang can be increased. The result is a better labor organization, reduction of the cost of foremen per mile, and generally greater efficiency. (3) Propelling a hand-car is a laborious job. With the motor-car the men reach the work fresh. (4) A motor-car can be operated up grades too steep for a hand-car. (5) In emergencies, such as washouts or wrecks, employees can be collected from a distance, which, without the motor-car, would require a special train. (6) By increasing the length of the section a greater range of location of the headquarters is obtained, and it is easier to hold the men.

The most serious disadvantages are the danger of breakdowns, with the resulting delay, and the danger of collisions with trains. The manufacture of motor-cars has reached a point of development where breakdowns result more frequently from ignorance or carelessness of the operator than from defective mechanism. After the foreman becomes accustomed to his car and learns how to make repairs these delays decrease. Some railways having a large number of motor-cars in service provide a traveling mechanic to inspect and repair each car at intervals of 1 or 2 months. Very strict rules for the operation of motor-cars should be put in force to prevent collisions or other accidents. At each telegraph or telephone station the foreman should communicate with the dispatcher. At especially bad curves flagging should be done. At night the cars should carry proper lights. A limit should be set for the maximum speed. When approaching highway crossings extra watchfulness should be observed.

The advantages of the motor-car for bridge-gangs and other traveling gangs are even greater than for section-gangs because of the greater distances to be traveled and the larger number of men affected. Various roads have estimated the increase in efficiency of the maintenance forces as a result of the use of motor-cars at from 25 to 50 per cent. The greatest improvement has been on single-track and double-track lines. On three- and four-track lines, where sections are short and trains are frequent, the advantages of motor-cars for section-gangs are much less pronounced. However, the advantages of their use for traveling gangs are the same as on single-track roads.

The conditions which will be met on the road should be studied carefully before adopting a type of car. A light engine is manufactured which can be placed on the old hand-car. This has given satisfaction where gangs are small. Inspection motor-cars and -velocipedes are made which weigh from 300 to 400 lb. and have a capacity of one to three men. The engines of these cars develop from 2 to 4 hp. The section motor-car should have an 8- to 10-hp. engine. Larger cars for bridge-gangs and covered inspection-cars have engines of 12 to 15 hp. The motors may be either air-cooled or water-cooled. The American Railway Bridge and Building Association makes the following recommendations regarding motor-cars:[1]

"The car should be as light as is consistent with the requisite strength and should not weigh more than 1000 lb. It should be designed so that the greater part of the weight is on the axle with the loose wheel to enable men to take it off the track easily. If water-cooled, the use of small pipes that freeze easily in cold weather should be avoided and the water-cooling apparatus should not be added at the expense of very much additional weight."

"The car should be designed so as to run at the same speed in either direction with equal safety. The motor should be started with the car at rest and the car started by use of a clutch or belt."

"The maximum speed should be not more than 20 miles an hour. It is very desirable to have at least two speeds in either direction to enable it to pull heavy loads over steep grades at low speed and to increase the speed where the grades are lighter."

"The car should be designed as simply as possible and with a view of having all parts easily accessible."

261. Work Equipment.—This includes all machines which permanently ride on the rails or are permanently mounted on cars or floating equipment. Under this heading come ballast-cars, ballast unloading-cars, bridge- and

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[1] 1913 Proceedings, Am. Ry. Bridge and Building Assn., page 237.

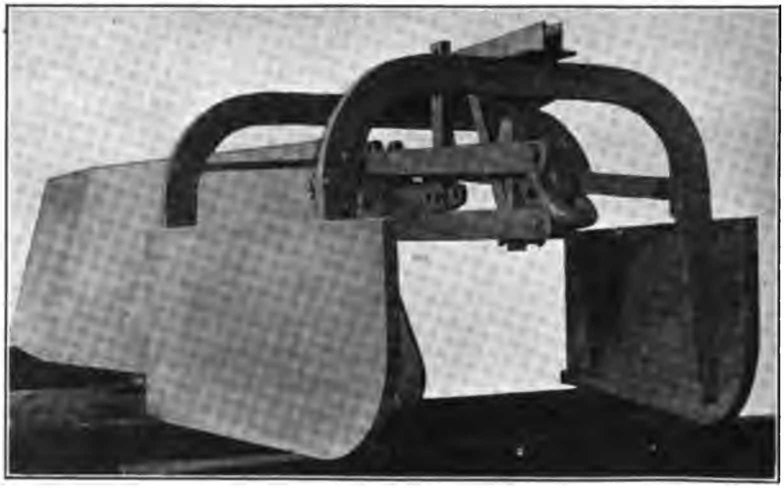

FIG. 206.—Center plow with attached pilot-plow.

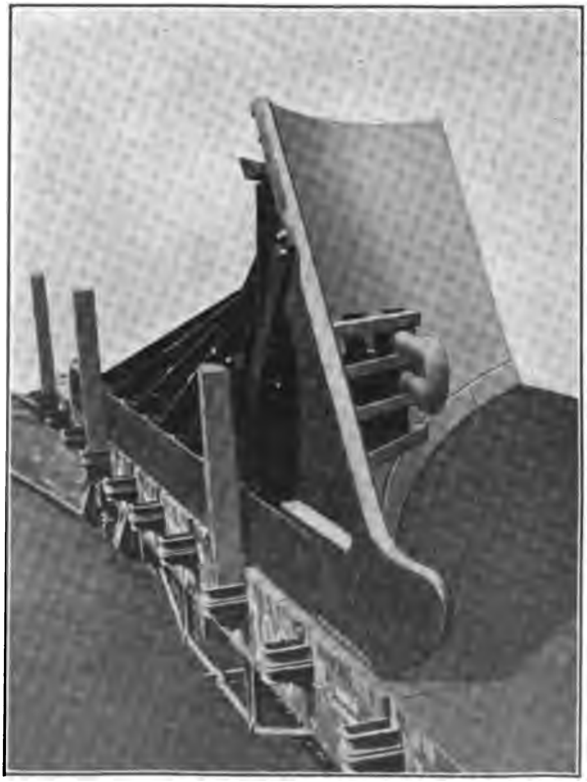

FIG. 207.—Bucyrus side plow.

painters'-cars, derrick-cars, pile-drivers, ditching-machines, steam-shovels, rail-handling machines, and snow-handling machines.

Ballast or excavated material loaded on flat cars may be unloaded by hand or by plow. An unloading-plow is a heavy wedge-shaped metal drag slightly less in width than the distance between standards or sides of a car.[1] Unloading-plows are of two general forms, namely, center and side plows. A Bucyrus center plow is shown in Fig. 206. A pilot-plow or forward plow, consisting of a wing on each side set at a small angle, is attached to the center plow shown. The pilot-plow is driven direct from the rear plow by means of braces from the nose of the latter. The wings of the pilot-plow are attached to the arms of heavy arches. A platform is provided at the forward end of the center plow so that it can be weighted to assist in holding down the nose, when necessary. The weight of a plow of this kind is from 6100 to 13,400 lb.

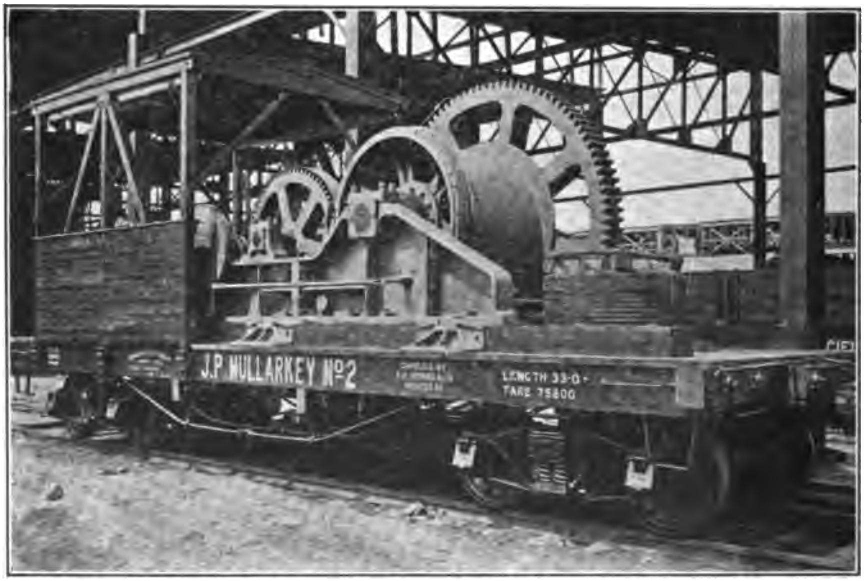

FIG. 208.—Lidgerwood unloading-car.

Figure 207 shows a Bucyrus side plow. This type of plow is made right-hand or left-hand. The moldboard is curved so that the entering angle at the nose is quite sharp. This greatly reduces the transverse pressure of the material against the plow near the forward end, and the liability to break the car-standards is reduced. The nose is bent slightly inward so that it will not strike the stakes. Plows of this type weigh from 4750 to 9200 lb. They unload the material on one side only. Both forms of plows can be used either on cars with swinging side doors or on flat cars with stakes or standards. The brakes of all cars must be set securely when unloading-plows are being operated.

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[1] Unloading-plows are roadway machines but are described here in connection with unloading-cars.

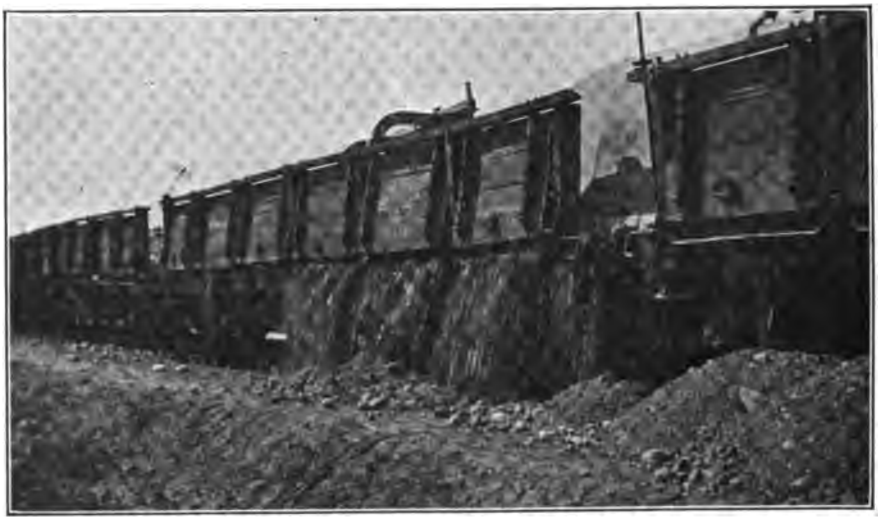


FIG. 209.—Unloading with a center plow from swinging side-door cars.

The unloading-plow is drawn by a heavy ballast-cable extending from the plow to the unloading-car at the front of the train. A large drum, with its driving mechanism, is mounted on the unloading-car, and the ballast-cable is wound upon this. Figure 208 shows a Lidgerwood unloading-car. Material being unloaded with a center plow from cars with swinging side doors is shown in Fig. 209. The plow is similar to the one shown in Fig. 206.

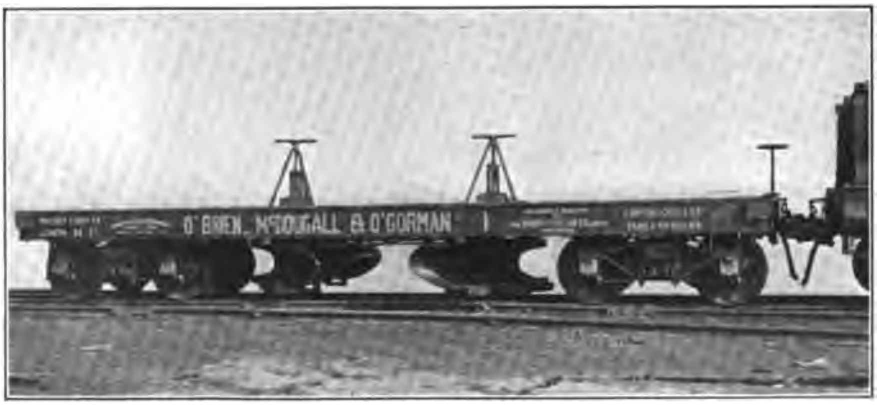


FIG. 210.—Plow- or spreader-car.

The plow-car shown in Fig. 210 is used to level ballast or other material dumped in the center of the track, and also can be used as a flanger-car for removing snow. Two plows pointing in opposite directions are mounted under the car so that the car can be operated in either direction. The plows are raised and lowered by hand-wheels mounted on the platform of the car. When ballast is dumped from hopper cars an

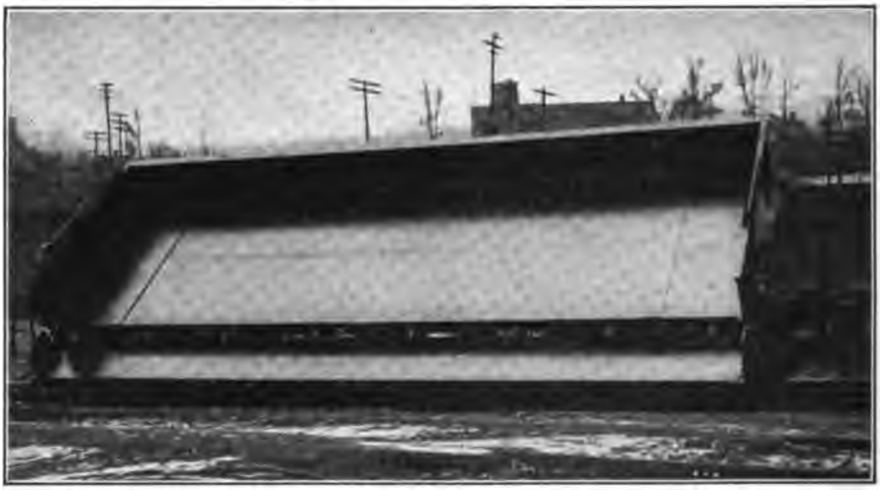


FIG. 211.—Clark extension-side dump-car; side view.

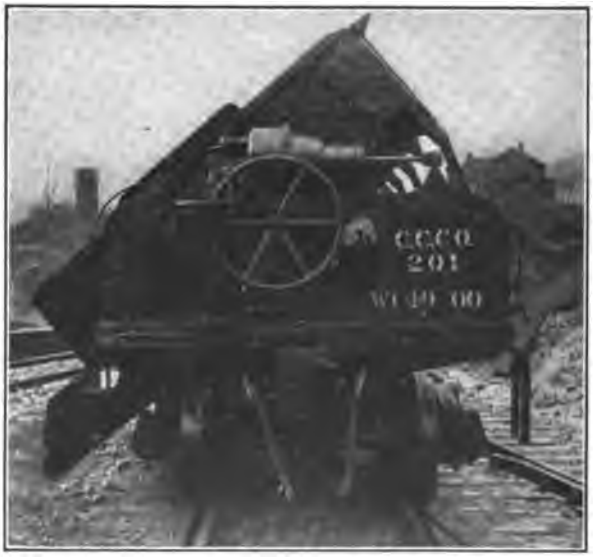


FIG. 212.—Clark extension-side dump-car; end view.

improvised ballast-spreader can be made by placing two ties across the rail in front of the rear truck of the last car and slowly moving the train ahead. The wheels push the ties ahead of them along the rail and the ties level the ballast. A car equipped with wings for trimming the ballast is used by a few railways.

Figures 211 and 212 show an 80,000-lb. capacity all-steel Clark extension-side dump-car. The car has a volume of 16 cu. yd. when level full, and 26 cu. yd. when heaped to an angle of 30°. The car can be dumped by hand or by air in the same manner that the air-brakes are operated, and can be dumped to either side. Latches between the underframe and body bolsters, operated either by hand or by air, secure the body of the car when closed. A Hart-Otis side-dump ballast-car is shown in Fig. 213. This car also is of all-steel construction.

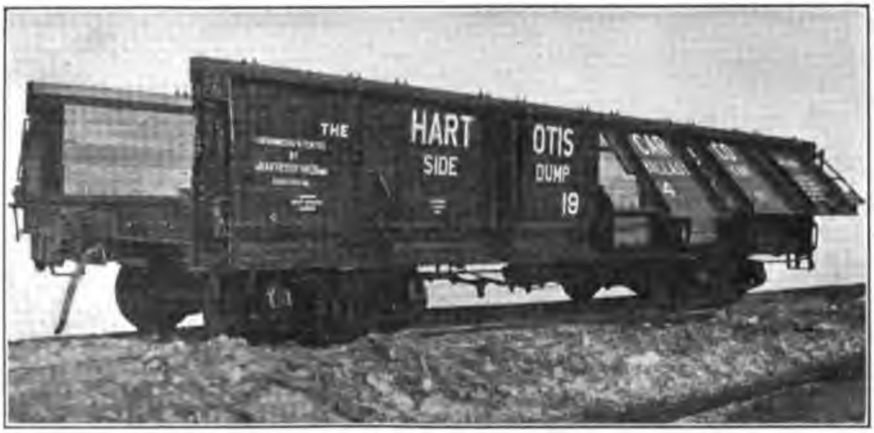


FIG. 213.—Hart-Otis side-dump ballast-car.

Ditching-machines are of two general types: those which load the dirt upon cars, and those which push the dirt out of the end of the cut. The Marion, Barnhardt, and American Railroad Ditcher are really small steam-shovels made so that the arm swings at right angles to the track and carries a small dipper which takes the dirt out of the ditch and loads it on the cars back of the ditching-machine. The Mahony ditcher is equipped to drag the plow along the ditch and the dirt is pushed out of the end of the cut. The plow is dragged by a Lidgerwood unloading-machine or by running the locomotive ahead.

Derrick-cars and locomotive-cranes are used for heavy lifting of all kinds. When rail is loaded and unloaded by machine, the work is usually done by a derrick-car, ditching-machine, or locomotive-crane. Pile-drivers are of three general forms: land or skid drivers, those permanently mounted on ordinary cars or barges; and locomotive pile-drivers. A derrick-car and two Bucyrus locomotive pile-drivers are shown in Fig. 214 at work repairing a 600-ft. trestle on the Pennsylvania Lines West, at Loudonville, Ohio, which was washed out during the flood of March, 1913. The leaders of these pile-drivers are at the outer end of a cantilever arm which can be rotated horizontally. The machine builds the trestle ahead of itself. The leaders can be inclined laterally,

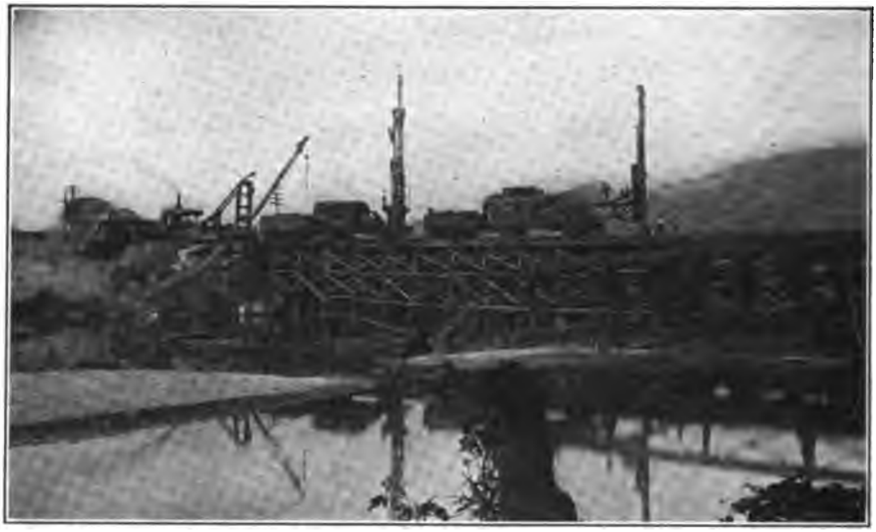


Fig. 214.—Derrick-car and locomotive pile-drivers repairing trestle.

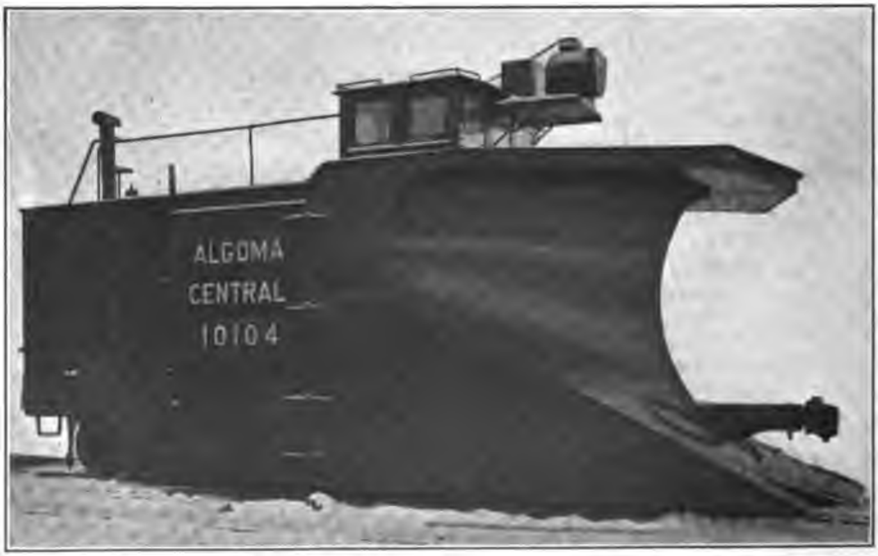


Fig. 215.—Push or wedge snow-plow.

and when not in use fold back upon the swiveling frame or cantilever arm.

On large jobs of laying rail, power-operated rail-saws and rail-benders should be used. These may be permanently mounted on flat cars, often having a canopy covering, or may be located in the general shops. A bridge-car used by traveling bridge-gangs is shown in Fig. 141. A painters'-car is arranged similarly.

262. Snow-handling Machines.—A pilot-plow is a small wedge-plow mounted on the pilot of the locomotive. It can be used only for a light fall of snow. The principle of the flanger-car is similar to that of plow-car shown in Fig. 210. The flanger clears the snow from the top of the rail and clears a flangeway 6 to 10 in. wide inside the rail. The flanger must be arrranged so that it can be quickly raised and lowered in order to clear stock-guards, switches, etc. It may be operated by hand or by air. Flangers may be mounted on the snow-plow, on the locomotive, or on special flanger-cars. Before the first fall of snow all temporary guard-rails, planks at farm crossings, and all other obstructions not absolutely needed between the rails, should be removed to facilitate the use of flangers.

An improved form of push-plow is shown in Fig. 215. The plow and car are of all-steel construction. The snow is raised by the incline of the plow before it is thrown from the track, so that it will clear a snow bank 6 to 8 ft. high. A folding wing is placed on each side of the plow. This is operated from inside the car. In the illustration the name of the railway is painted on the wing. A rotary snow-plow consists of a revolving wheel carrying cutting blades, mounted at the front of a heavy car. The car rests on two four-wheel trucks and contains the boiler and engine which operate the rotary. The wheel of the rotary is incased in a drum with a square front. A chute is provided in the top of the drum from which the snow is thrown by centrifugal force. The chute is arranged so that the snow can be thrown on either side. A pilot is stationed at the front of the car and directs the movements of the rotary and pusher locomotive. Also he operates the flangers on the rotary. Usually one heavy consolidation locomotive is sufficient to push the rotary. The plow should not be coupled at the front of a train because of the difficulty of quickly stopping and starting. A rotary should not be used in drifts deeper than the hood. When the snow is deeper than this the top of the drift should be shoveled away until the depth is such that the rotary can be used without danger of stalling.

A snow-crab is a V-shaped plow having the vertical edges of the two wings shod with iron to act as cutting edges. The flare of the wings can be regulated by chains attached to a wheel mounted on a flat car between the wings. These chains also prevent the wings from spreading. The machine is moved backward through the snow cut and the wings drag the snow from the side of the cut down upon the track where it can be thrown out by a rotary.

263. Rental of Equipment.—In order to determine the cost of executing the various kinds of work in the department of maintenance of way and structures, and to make proper charges against other corporate properties, it is necessary to estimate the length of life of each machine used, the cost of maintenance, and the interest on the investment, and then assign a rental rate to the machine. A list of rates for rental of equipment, computed in this way, is given in Table 24. As the original costs of locomotives and other machines vary approximately as the weights of each kind of machine, the rental rates vary in a similar manner.

TABLE 24.—RATES FOR RENTAL OF EQUIPMENT

Equipment	Rental per day	Equipment	Rental per day
Ballast-cars, 30 to 40 tons	$0.15	Pile-driver, land and skid	$0.50
Bridge-traveler with engine and tools	3.00	Pile-driver, scow and steam	1.00
Caboose, four-wheel	0.15	Pneumatic riveting-machine and outfit	2.50
Concrete-mixer	0.50	Rail-bending machine	1.50
Derrick tender	0.20	Rail-sawing machine	5.50
Dredger, suction	60.00	Rock-crusher, complete	7.00
Dredger, ordinary on large jobs	30.00	Rubbish-cars	0.10
Flat car, wooden	0.10	Scale test-car	0.75
Dump-scow	0.50	Side dump-car, steel, 50-ton	0.20
Flanger, ice	1.25	Snow-plow, rotary	15.00
Lidgerwood unloader	2.00	Snow-plow, wedge	2.50
Locomotives:		Stationary engine	0.50
Atlantic, simple and compound	10.00	Steam-boiler	0.50
Pacific, simple and compound	11.00	Steam-shovel, 1 to ½ yd	5.00
Twelve-wheel, simple and compound	15.00	Steam-shovel, 2 ½ yd	6.00
Switch	7.00	Steam-shovel, 3½ yd	7.00
Consolidation, simple	15.00	Steam-shovel, 5 yd	8.00
Mogul, simple	15.00	Steam-roller	1.50
Ten-wheel, simple	11.00	Tank-car, water	0.50
Consolidation, compound	22.00	Tug, small, on large jobs	7.50
Mogul, compound	19.00	Wrecker, hand	0.40
Ten-wheel, compound	20.00	Wrecker, steam, up to 50 tons	4.00
Locomotive-crane	3.00	Wrecker, steam, over 50 tons	6.00
Oil-sprinkling car	0.50		
Outfit-car, old coach	0.20		

CHAPTER XIX

RECORDS

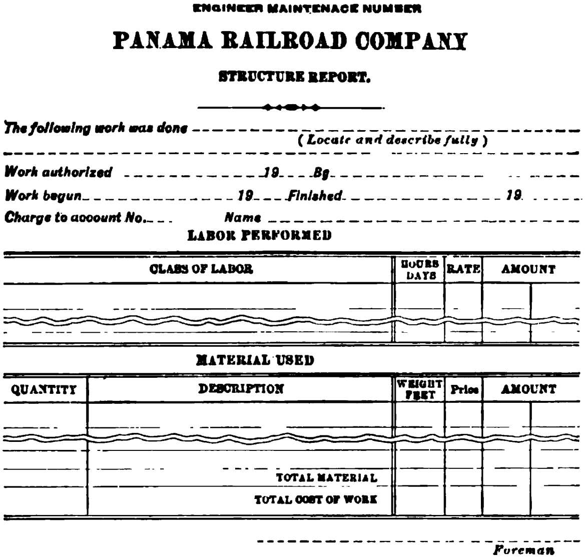
264. Records and Reports.—The methods of recording the activities of the various departments of railways in the United States have evolved from scattered, unsystematic, and ununiform practices to a rather elaborate system, the general features of which are standard on most railways.

Records may be defined as information or data in tabular, statement, or graphical form relating to physical characteristics, conditions, costs and other information which is desirable for record. Reports are the medium through which information is transmitted from one person to another and from which records and accounts are prepared or compiled in the filing office. Duplicate copies of all records, maps, etc., should be kept in widely separated localities, so that the loss in case of fire or accident will be greatly reduced.

Various reports are required by State and Federal railway commissions. These should be incorporated in the standard forms adopted by the railway. In the past there has been some conflict detween the reports required by State and Federal Commissions. So far as possible the general forms of the railway should be used for reports in all departments. For example, it is possible to use one form for reporting time in all departments if the form is designed with this in view. However, each department requires certain special forms which should be designed in cooperation with the accounting department, since the reports made on these forms are the foundation of the entire accounting system of the department using them. The special forms required in the work of maintenance of way and betterments may be classified as (1) bridge forms, (2) track forms, (3) general forms, (4) construction forms, (5) accounting forms, and (6) record forms.

265. Bridge Forms.—The necessary bridge forms are for reports of bridge inspection, repairs to structures, and materials. A separate report of inspection may be made by bridge-inspectors for each structure inspected and the results transferred in the office to a summary sheet showing all structures inspected during a given inspection; or the notes of all structures inspected may be entered on one form at the time of inspection. The data which should be shown on the reports are the number of the structure, the date of inspection, the location of structure, its condition, work recommended to maintain the structure in a good condition, and work which must be done to keep the structure safe. The summary should show the action taken on the work recommended in the original report. If the field notes of different structures are entered on the same form, the numbers of the structures to be inspected should be previously written on the form. Also a form for the report of the annual or semi-annual general bridge inspection is necessary. It should be ruled in columns to show the number of the structure, date of inspection, location, kind of structure, necessary data, general condition, description of work required, and recommendations. The report should be signed by all members of the inspection party.

A structure report should be made of the repairs to each structure. It should show the location of the structure; the dates the work was authorized, commenced, and finished; the unit, quantity, price, and total cost of each kind of material; and the number of days and cost of each kind of labor. The structure report used by the Panama Railroad is shown in Fig. 216.



ENGINEER MAINTENACE NUMBER

PANAMA RAILROAD COMPANY

STRUCTURE REPORT.

The following work was done ______________________
(Locate and describe fully)

Work authorized ______________ 19___ *Bg*______________

*Work begun*______________ 19___ *Finished*______________ 19_____

*Charge to account No.*___ *Name* ______________________

LABOR PERFORMED

CLASS OF LABOR	HOURS DAYS	RATE	AMOUNT

MATERIAL USED

QUANTITY	DESCRIPTION	WEIGHT FEET	Price	AMOUNT
	TOTAL MATERIAL			
	TOTAL COST OF WORK			

____
Foreman

FIG. 216.—Structure report; Panama Railroad.

The bridge material report should be made out at the end of each month by the foreman of bridges and sent to the bridge engineer. It should show the unit measure and quantity of each kind of material on hand at the beginning and end of the month, the date the material was received, the quantity used and otherwise disposed of and general remarks.

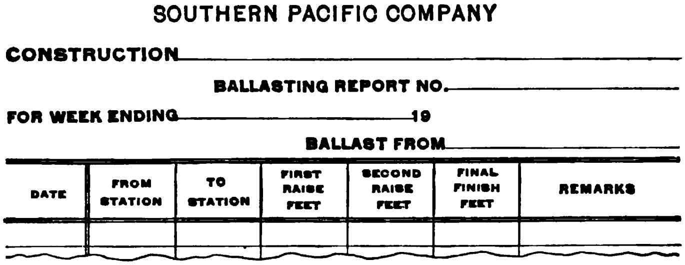
266. Track, General, and Construction Forms.—At the end of each day's work the section-foreman should fill out and send to the supervisor by the next train a form showing the name of each man of the gang, his identification number, rate of pay and occupation, a description of the work and time of each man on the work, and the total time of each man. Frequently a separate record is kept of the work done on sidings. At the end of each month the section-foreman should make a track material report showing, for each class of material, the unit measure; quantity on hand at date of last report; amount received since by shipment and taken out of track; total to be accounted for; amount shipped away, used in new track, main track, and sidings; total disposed of; and total on hand at date of report. The material covered by the report includes, first- and second-class new rails, relaying rails, scrap, track- and switch-ties, bolts, spikes, tie-plates, nut-locks, rail-braces, tie-plugs, splice-bars, insulating end posts, switch-points, frogs, guard-rails, switch-rods, slide-plates, switch-stands, switch-locks, railroad crossings, switch-lamps, salt, oil, stock-guards, lumber, fence-posts, wire fencing, telegraph-wire, etc. The list of materials should be printed on the form, space being left for entering miscellaneous material not listed. In some cases a general form is used for reporting both bridge and track materials.

At the end of the month each foreman should send a maintenance of way department tool report to his supervisor. The report should show the division, gang, and date of report. A list of tools standard with the railway using the form should be printed in the first column of the form. Additional columns should be provided to show the tools on hand at date of last report, tools received since last report, tools sent to shop for repairs, tools broken or worn out since last report, and tools on hand on date of report. The list of tools printed on the report should be such that the same form can be used both for bridge and track tools. Besides the daily time report mentioned in the first part of the Article, each section- and bridge-foreman must keep a monthly time roll, showing the distribution of all labor and teams employed and explaining all overtime, errors and delays. The form should be designed so that it can be used for both track and bridge forces. The data contained on these and the daily report forms are transferred to the proper forms for reporting to the State and Federal Commissions.

Construction forms are used for estimating the cost of new construction of track, buildings, bridges, and water service. The front of the sheet should be ruled to show, for each item, the cost of labor; quantity, unit cost, and total cost of material; and total cost. A list of items which must be shown in the estimate and a description of same may be printed on the back of the sheet. A description of the work covered by the estimate, authority number, date, name of estimator, and distribution of cost to maintenance, operation, betterment, or outside agencies should be entered on the form. Other construction forms are used to report the progress of work. A form used by the Southern Pacific Company to report the weekly progress of ballasting or reballasting is shown in Fig. 217.

267. Accounting and Record Forms.—The authority for work should be based on carefully prepared estimates and the authorization of the expense should be made formally by the executive officers. The following forms may be used for this purpose:

1. Application for expenditure. This should give a concise description of the work and an estimate of cost in detail, showing the amount to be charged to new work or additions, betterments, renewals, or replacements, and outside agencies. The distribution of charges as between additions, replacements, etc., should be made according to Federal requirements. If any variation from the original construction is contemplated in a replacement, mention should be made of it, such as substituting a concrete for a wooden culvert. *Renewing* means restoring the original of any structure. Under other conditions the items of the estimate should be described as *strengthening*, *changing*, *altering*, *extending*, etc. When there is any value of the material to be recovered or released it should be shown as a credit. The disposition made of all abandoned structures and material should be shown. The form is signed by the engineer of maintenance of way, chief engineer, or other official or officials according to the particular organization. A form for application for expenditure is shown in Fig. 218.



SOUTHERN PACIFIC COMPANY

CONSTRUCTION ____________

BALLASTING REPORT NO. ____________

FOR WEEK ENDING ____________ 19

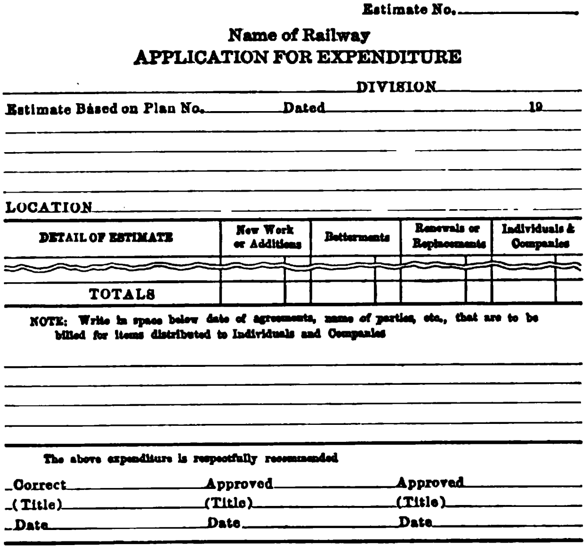
BALLAST FROM ____________

DATE	FROM STATION	TO STATION	FIRST RAISE FEET	SECOND RAISE FEET	FINAL FINISH FEET	REMARKS

FIG. 217.—Ballasting report; Southern Pacific Company.

2. Authority for expenditure. This form should be used by the highest executive officer to inform the persons signing the application for expenditure that the work shown in the application is authorized. It should show a concise description and location of the work, the total estimated cost of the work, a reference to the number or numbers of applications which it covers, and the distribution of expense. This form, properly signed, is the authority for the work mentioned in it to be done; but the expenditure for the work must not exceed the amount authorized. If the original authority is insufficient to complete the work, additional authority must be obtained. Also, the length of time

during which the authority is effective is limited, the authority usually expiring with the fiscal year in which it is issued. Work incomplete at that time requires a new authority for the following year's expenditures. This form does not authorize the payment of money if used with the form for appropriation for expenditure. If used alone it constitutes both the authorization for the work and the authorization for the payment of money for the work. The distinction between the two forms is that one is the authority for the engineer in charge to have the work done, while the other is the authority for the finance officials to pay for such work. Figure 219 shows a form for authority for expenditure.



Estimate No.________

Name of Railway
APPLICATION FOR EXPENDITURE

________DIVISION________

Estimate Based on Plan No.________Dated________19____

LOCATION________

DETAIL OF ESTIMATE	New Work or Additions	Betterments	Renewals or Replacements	Individuals & Companies
TOTALS				

NOTE: Write in space below date of agreements, name of parties, etc., that are to be billed for items distributed to Individuals and Companies

The above expenditure is respectfully recommended

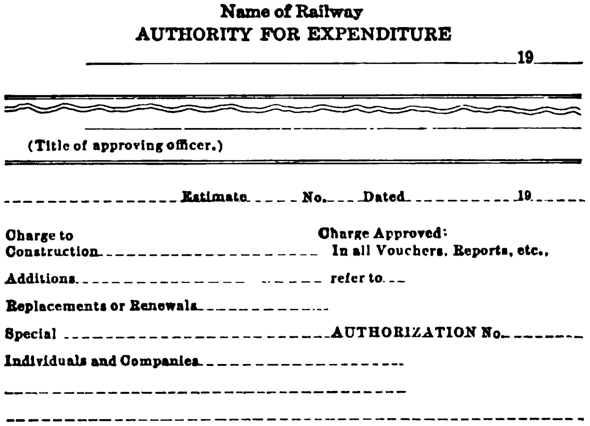
_Correct________Approved________Approved________
_(Title)________(Title)________(Title)________
_Date________Date________Date________

FIG. 218.—Application for expenditure.

3. Appropriation for expenditure. This form is not always used. When used it is used with the form for authority for expenditure. The authority it conveys for appropriation is limited in the same way as the authority for expenditure described above. The form used is practically the same as that used for authority for expenditure, shown in Fig. 219.

After the authority for expenditure has been issued, a monthly report of expenditure on this authority should be made by the engineer in charge of the work. The report should show the authorized expenditure for each item, amount expended during current month, previous expenditures, total expenditures to date, total estimated amount of expenditures still necessary and necessary for ensuing month, increase or decrease over original estimate, and remarks. The authority number, amount of authority, description and location of work, and date commenced and completed, if completed, also should be given. This form is shown in Fig. 232. The complete statements of all expenditures of the maintenance and engineering departments are made by the auditing department, based on reports similar to the monthly report of expenditure just described. It is the duty of the auditor of disbursements to see that the expenditures do not exceed the authorized amounts, or to call the attention of higher officials to the over-runs as they occur.

When the work is completed a report of the record cost of the work should be made. The form should show the authority number, total amount authorized, actual cost, date work was commenced and date completed, and the quantity, unit measure, price, and total cost of each item.



Name of Railway
AUTHORITY FOR EXPENDITURE
______________________19______

(Title of approving officer.)

______ Estimate ____ No.___Dated __________19______

Charge to
Construction____________________ Charge Approved: In all Vouchers, Reports, etc.,
Additions________________ ______ refer to__
Replacements or Renewals______________
Special ____________________AUTHORIZATION No.________
Individuals and Companies__________________

Fig. 219.—Authority for expenditure.

A form should be prepared for recording all deeds, concisely showing all general information conveyed by the deed. Contracts and leases should be entered on another form.

268. Maps and Profiles.—Each railway is required to file three classes of maps with the Interstate Commerce Commission, namely, right-of-way and track map, station maps and profile. Besides these there are certain records and charts which each railway should have kept for its own convenience. These are records of ballast-renewals showing kind, depth, mileage, year placed, etc.; records showing the weight, year laid, etc., of rails; and track charts showing complete information as to the gradients, alignment, location of yards, sidings, signals, structures and other physical features. The records of ballast- and rail-renewals may be kept either in a tabular or diagrammatic form. Figure 220 shows a tabular form for a progress record of ballast-renewals, in which the renewals for each quarter of the year are entered. Figure 221 is a diagram or chart which gives similar information. The diagram

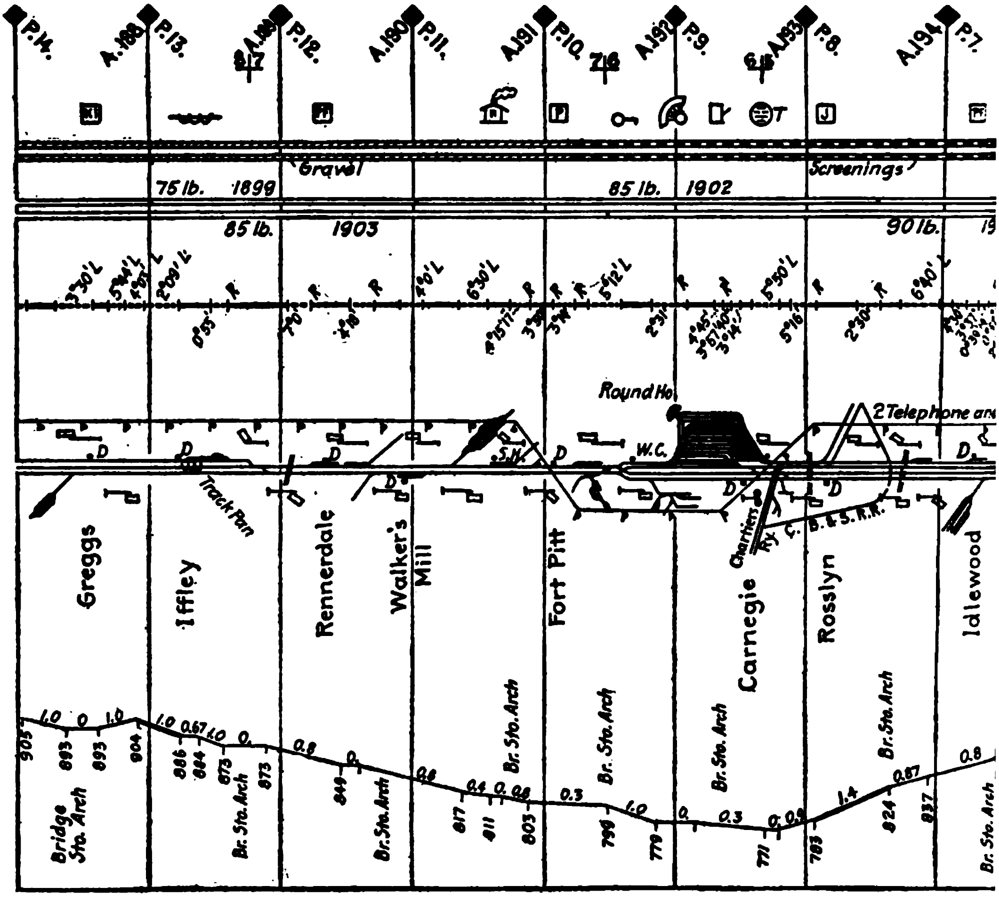
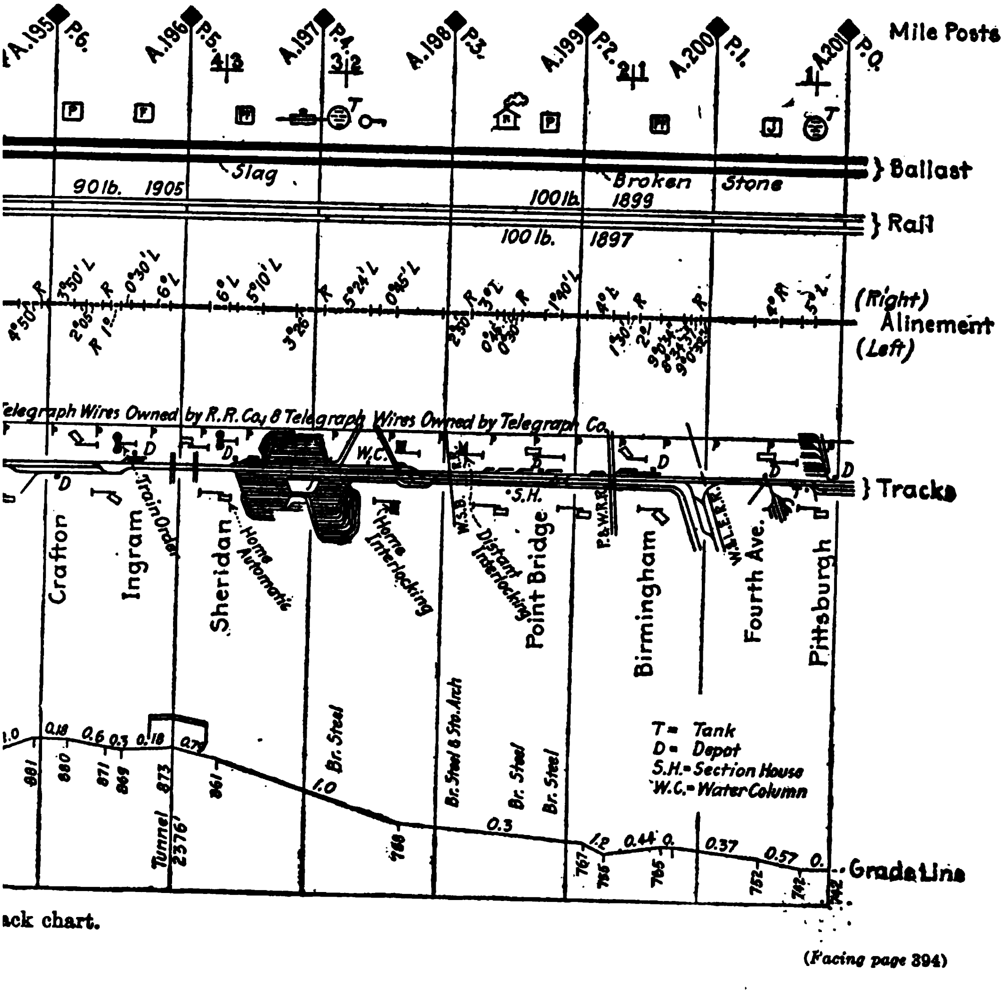

P.14.
A.188
P.13.
A.189
P.12.
A.190
P.11.
A.191
P.10.
A.192
P.9.
A.193
P.8.
A.194
P.7.
Gravel
Screenings
75 lb.
1899
85 lb.
1902
85 lb.
1903
90 lb.
Round Ho
2 Telephone an
W.C.
S.H.
Track Pan
Chartiers Ry.
C. B. & S. R.R.
Greggs
Iffley
Rennerdale
Walker's Mill
Fort Pitt
Carnegie
Rosslyn
Idlewood
Bridge Sto. Arch
Br. Sto. Arch
905
893
893
904
886
884
873
873
849
817
811
805
799
779
771
783
824
837
1.0
0
1.0
1.0
0.67
1.0
0.
0.8
0.
0.8
0.4
0.
0.8
0.3
1.0
0.
0.3
0.
0.9
1.4
0.87
0.8

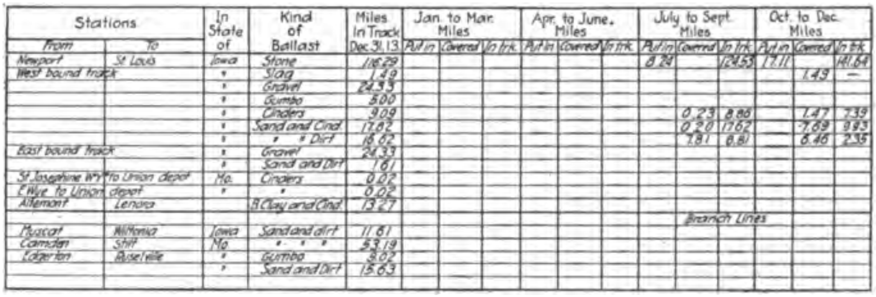
Fig. 222.—



…ack chart.

(*Facing page 394*)

should be drawn to a scale of about ½ in. to the mile and should show the names of stations; divisional points; state lines; 5- or 10-mile points; kind, depth and mileage of ballast on a certain date taken as the beginning of the diagram; and the kind, depth and mileage placed, and the number of authority for expenditure, for each subsequent year. A combination of the tabular and diagrammatic forms affords an excellent means of obtaining a permanent and useful record. The quarterly renewals are entered in the table and at the end of the year the data are taken from the table and plotted on the diagram. The diagram shown is ruled in groups of five parallel lines, each group representing 1 year. In the upper interlinear space the kind of ballast is shown graphically. In the second space the depth and kind of ballast is entered. In the third space is entered the serial number of the authority for expenditure; and in the last space is shown the mileage. The record may be for each section or the sheets may be made large enough to show a considerable length of track. Similar records are prepared for rail-renewals. Figure 222 is a track-chart, which shows diagrammatically all general physical features.



Stations		In State of	Kind of Ballast	Miles In Track Dec. 31, 13	Jan. to Mar. Miles			Apr. to June. Miles			July to Sept. Miles			Oct. to Dec. Miles		
From	To				Put in	Covered	In trk.	Put in	Covered	In trk.	Put in	Covered	In trk.	Put in	Covered	In trk.
Newport	St Louis	Iowa	Stone	116.29							8.24		124.53	17.11		141.64
West bound track		"	Slag	1.49											1.49	—
		"	Gravel	24.33												
		"	Gumbo	5.00												
		"	Cinders	9.09								0.23	8.86		7.47	7.39
		"	Sand and Cind	17.82								0.20	17.62		7.69	9.93
		"	" " Dirt	16.62								7.81	8.81		6.46	2.35
East bound track		"	Gravel	24.33												
		"	Sand and Dirt	1.61												
St Josephine Wy	to Union depot	Mo.	Cinders	0.07												
E Wye to Union depot		"	"	0.02												
Altamont	Lenora		B Clay and Cind	13.27												
												Branch Lines				
Muscat	Miltonia	Iowa	Sand and dirt	11.61												
Camden	Stitt	Mo	" " "	53.19												
Edgerton	Buselville	"	Gumbo	3.02												
		"	Sand and Dirt	15.63												

Fig. 220.—Tabular form for progress record of ballast-renewals.

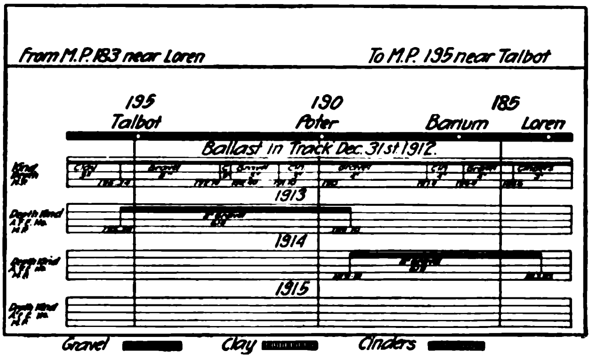


Fig. 221.—Diagrammatic form for recording ballast-renewals.

269. Right-of-way and Track Map.—The right-of-way and track map should be a true horizontal projection of the right-of-way, tracks and other structures, plotted continuously between terminal points. The following are the most important data to be shown:

1. The width of right-of-way at all changes in width, and the stationing of such points.

2. A schedule showing the name of grantor and grantee, kind of instrument, date, book and page where recorded, for all deeds, leases, ordinances, franchises, grants, or other method by which the railway acquired each piece of property.

3. Boundary lines of all detached land. Detached land includes land used by the railway as a carrier but detached from the right-of-way; and land either adjoining or disconnected from the right-of-way, but not used for the purpose of a common carrier.

4. The stationing of the intersection of all private property lines, section, township, county, state, or other government lines, streets and highways with the center line or base line of the railway.

5. The names of owners of all adjacent land.

6. The distance of the center line from nearby permanent land corners or monuments.

7. The center line of each main track and siding.

8. All railways crossed or joined, and whether the crossing is at, over, or under grade.

9. The stationing at each 1000 ft. and at all switches and all points where a change in horizontal alignment occurs, such as beginning of spiral, beginning of curve, etc.

10. The degree and central angle of each main curve and spiral.

11. A general outline of all improvements owned by the company, such as station- and office-buildings, shops, engine-houses, fuel and water stations, etc.

12. An indication by means of conventional signs of the location of bridges, trestles, culverts, tunnels, retaining walls, stock-guards, and mile-posts; block, interlocked, and train-order signals; pipe lines, sewers, etc. Where possible the stationing of these should be given.

13. The positions and names of water courses, highways, etc., and whether the highway is crossed at, over, or under grade.

The zero station or station of lowest number should be at the left side of the sheet and the general direction of the center line should be along the center of the sheet. Right-of-way and track maps to be filed with the Interstate Commerce Commission must be drawn to a scale of 1 in. equals 400 ft. or 1 in. equals 200 ft. The outside dimensions of the sheets must be 24 by 56 in., and 23 by 55 in. inside a single line border. If the smaller scale is used, not more than 4 miles of roadway should be shown on each sheet. If the larger scale is used, only half this length should be shown.

270. Station Maps.—Station maps are a supplement to right-of-way and track maps for terminals and other locations where the railway's property is too extensive and complicated to be shown clearly on the right-of-way and track map. If the land and improvements are too complicated to be shown clearly on one station map, two maps should be made, one showing details as to land, and the other showing the tracks, structures, and external land boundaries. Station maps should be drawn to a scale of 1 in. equals 100 ft. or 1 in. equals 50 ft. The size of the sheets should be the same as that of right-of-way and track maps. If the scale used is 1 in. equals 50 ft. tracks may be represented by rail lines.

271. Profiles.—Profiles are used for reference or record purposes and to show the progress of work being done. The following data should be placed on record and reference profiles:

1. The vertical projection of the original ground surface on center line of railway.
2. Rates of gradients, elevation of subgrade at all points where the rate of gradient changes and stationing at such points.
3. Stationing at each 1000-ft. interval, shown near lower border of sheet.
4. Vertical projection of all bridges, trestles, culverts, tunnels, and other roadway structures, stating the kind, general dimensions, and stationing of same.
5. Average penetration of piles in each bent of trestle, and depth of masonry foundations.
6. Existing mile-posts.
7. A detailed summary of construction quantities for each mile, including roadways, bridges, and culverts.
8. On the lower 2½ in. of the sheet, the center line of each track, developed into a straight line, with stationing and alignment notes of main curves and spirals; passing tracks; sidings; station-buildings; fuel and water stations· highway and railway crossings; waterways, etc. A scale of 1 in. equals 200 ft. may be used for transverse plotting.

Profiles filed with the Interstate Commerce Commission must be drawn on Plate A profile paper. The scales must be vertical, 1 in. equals 20 ft. and horizontal, 1 in. equals 400 ft.

A progress profile, based on the regular profile, is used to show information respecting the rate of progress of new construction. Each month's work is plotted in a different color. A chart at the bottom of the sheet shows the progress of track-laying, ballasting, surfacing, etc.

272. Maps and Profiles Required by the Board of Railway Commissioners of Canada.—The following is an abstract from the rules and regulations of the Board of Railway Commissioners of Canada, relating to the preparation and filing of maps and profiles:

1. Three copies of a map showing the general location of the proposed railway, the termini, principal towns on the proposed line, railways, navigable streams and tidewater crossed by or within a radius of 30 miles of the railway, and the general physical features of the country traversed by the railway, must be

sent to the secretary of the Department of Railways and Canals. Two copies are filed by the Minister and one is approved for the railway. The scale of the map is not less than 6 miles to the inch.

2. After the approval of the general location map, three sets of the following plans must be sent to the Secretary of the Board of Railway Commissioners: plan, profile and book of reference. The scale of the plan must be 1 in. equals 400 ft. The scale of the profile must be 1 in. equals 400 ft., horizontal, and 1 in. equals 20 ft., vertical. In prairie country the scale of the plan may be 1 in. equals 1000 ft.

3. If it is desired to alter the location or gradients of a line previously sanctioned by the Board three sets of revised plans, profiles, and books of reference must be sent to the Secretary of the Board, as before. Upon completion of the work application must be made to the Board for permission to operate the railway.

4. Within 6 months after the completion of the railway three sets of plans and profiles of the completed railway must be sent to the Board.

5. When it is desired to take additional lands for stations, snow protection, etc., an application—sworn to by the railway officers required to sign and certify plans—plan, profile and book of reference must be sent in triplicate to the Board. Ten days' notice of the application must be given the owner of the land.

6. Plans for branch lines shall be prepared the same as in No. 2, and one set deposited in the Registry Office. The Company must then give 4 weeks' public notice of its intention to apply to the Board in a newspaper published in the district through which the branch will pass. An application containing a copy of the public notice, and three sets of the plan, profile, and book of reference, then must be sent to the Board.

7. To apply for a railway crossing or junction, an application and three sets of plans and profiles of both railways for 1 mile on each side of the crossing must be sent to the Board. The horizontal scale of plan and profile is 1 in. equals 400 ft. The vertical scale of the profile is 1 in. equals 20 ft.

8. An application to the Board for the crossing of a highway must be accompanied by three sets of plans and profiles showing the railway for at least ½ mile and the highway for 300 ft. on each side of the crossing. The scales are as follows: plan, 1 in. equals 400 ft.; profile of railway, horizontal, 1 in. equals 400 ft., vertical, 1 in. equals 20 ft.; profile of highway, horizontal, 1 in. equals 100 ft., vertical, 1 in. equals 20 ft. The plan must show all obstructions to the view from any point on the highway within 100 ft. of the crossing to any point on the railway within ½ mile of the crossing. Ten days' notice and copies of the plans must be given the municipality and proof of such must be furnished the Board. Highway approaches must be 20 ft. wide. When the work is completed application must be made to the Board for permission to operate.

9. Before applying to the Board for permission to cross or locate structures upon navigable waters, beaches, etc., the site and general plans must be submitted to the Department of Public Works for approval of the Governor in Council. After this approval is obtained an application and two sets of detail plans, profiles, and specifications must be sent to the Board. The plans must show all details of substructure and superstructure. The profile must show elevation of

works, high and low water marks, cross-section of the stream, the name of the body of water, and the mileage of the structure.

10. All specifications and detail plans of bridges, tunnels, viaducts, trestles, etc., over 18 ft. in length must be approved by the Board before construction is commenced.

11. An application for new station-grounds and station-buildings must be sent to the Board, with plans in triplicate showing the location and details of structures and yard-tracks. Notice of the application and a copy of the plans also must be given the municipality affected, and proof of service must be furnished the Board.

12. General Instructions.—Plans Nos. 2 to 6 must show the right-of-way with lengths in miles; the names of terminal points; station-grounds, property lines, owners' names; area, length, and width of each parcel of land proposed to be taken; bearings of tangents; degree and central angle of curves; and all open drains, waterways, highways, railways, and private roads crossed or affected. If a width of right-of-way greater than 100 ft. is necessary to accommodate slopes and side ditches, cross-sections 100 ft. apart and extending to the limits of the proposed right-of-way must be placed on the plan. The datum of profiles should be sea level. Profiles must show gradients and curves, and also crossings of highways, railways, and waterways. The copy of the plan and profile retained by the Board must be on tracing linen. The book of reference must describe the portion of land to be taken in each lot traversed, giving numbers of the lots, the area, width, and length of the portion to be taken; and the names of owners and occupiers. The book of reference may be placed on the plan or on durable paper bound in the form of a book 7½ by 7 in. Plans, profiles, and books of reference must be dated and must be certified and signed by the President, Vice-President, or General Manager, and by the Chief Engineer of the railway.

273. Conventional Signs.—Standard conventional signs for use on topographical, right-of-way and track, and other maps are necessary in railway work. The American Railway Engineering Association has done a very valuable work in preparing a comprehensive list of conventional signs. The valuation work conducted by the Interstate Commerce Commission requires an unusual amount of map-making and, to insure that this be done on a uniform basis, the instructions of the Commission read, "The symbols used on maps and profiles shall be the standards recommended by the American Railway Engineering Association, in so far as they are applicable."

The standard practice in the past has been to show hydrography in blue, relief in brown, and all other features in black. In some cases red is used for dimension lines, center lines, and grade lines and elevations on profiles, etc. Though adding to the appearance of the original, colored inks are objectionable when the map must be reproduced photographically or by blue printing. Their use should be avoided. Many draftsmen show a curve in the horizontal alignment on the profile by a curve drawn above or below the base line. This is an objectionable method because the topography is distorted and there is likely to be a difference of opinions as to whether a curve above the line means a curve to the right or left. A better method is to show tangents by solid lines and curves by dotted lines, using the letters R and L to indicate the direction of the curves.

The standard conventional signs for use on topographical and right-of-way and track maps, from the Manual of Recommended Practice, of the American Railway Engineering Association are shown in Figs. 223 to 231. All signs are to be shown in black. The titles and wording on the figures are self-explanatory.

274. Storehouses.—The organization of a railway makes it impossible to secure materials by direct purchase when and in the quantity required for construction, maintenance, and operation. This has brought about the development of the storehouse, where a reserve stock of materials is maintained which is drawn upon to meet the demands as they arise.

The operating expenses of Class 1 and Class 2 railways in the United States amounted to $2,169,282,316 for the year ending June 30, 1913. Carpenters, machinists, other shopmen, section-foremen, other trackmen, and other employees and laborers, whose efficiency depends to an appreciable extent upon their being supplied with proper tools and materials, were paid in wages $665,917,087, or 30.7 per cent. of the total operating expenses. The materials and supplies on hand at the end of the year were valued at $299,290,390. The annual interest charge at 5 per cent. on this investment would be $14,964,520, about 2.2 per cent. of the amount paid during the year to the class of employees mentioned. There was surprisingly little fluctuation in this percentage for a number of years preceding 1913. In some cases it may be possible to reduce the amount of materials, but a reduction in stock of 50 per cent. would mean an annual saving of only 1.1 per cent. of the wages annually paid the above-mentioned employees. A very slight loss in their efficiency, resulting from a failure to secure materials and tools when needed, would mean a greater financial loss than the amount saved by reducing the investment in stock. Therefore, it may be said that the most important purpose of the storehouse is to promptly deliver materials and supplies as requisitioned, so that the delays to labor while awaiting receipt of the supplies will be a minimum.

On the other hand, heavy losses may result from over-stocking, due to deterioration and obsolescence of the materials. When the storehouse department is well organized the losses which occur through lack of material generally are less than the losses which occur through overstocking.

The storehouse should be located at the point of greatest consumption or at a point where the total movement of all materials delivered to

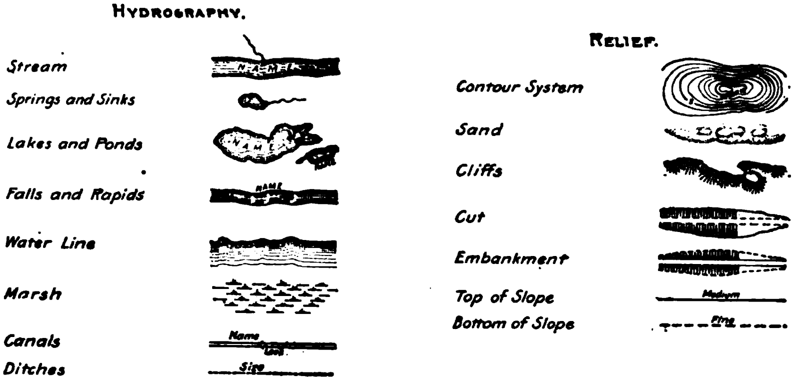


Fig. 223.—Hydrography and relief.

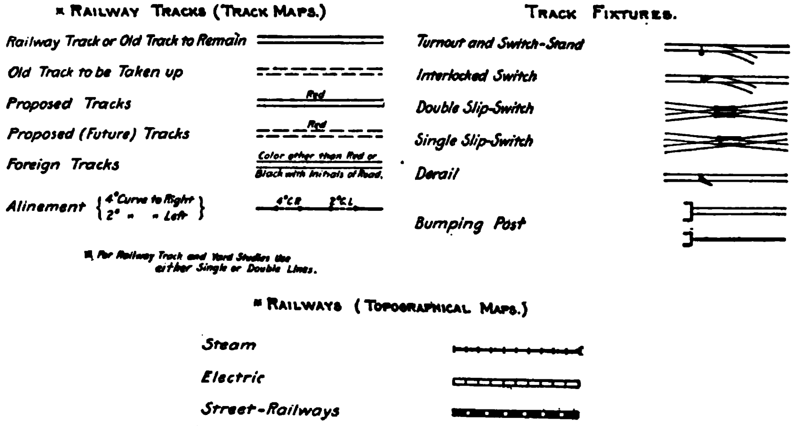


Fig. 224.—Tracks and track fixtures.

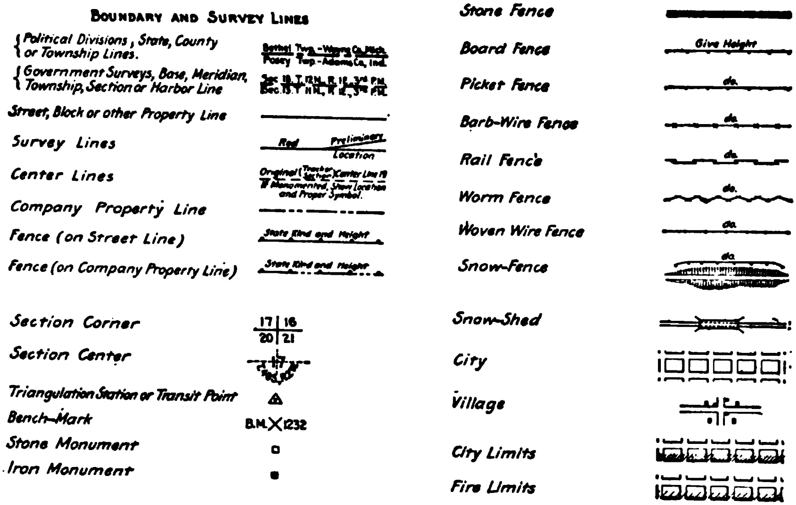

Boundary and Survey Lines
{Political Divisions, State, County or Township Lines.
Bethel Twp.-Wayne Co., Mich.
Posey Twp.-Adams Co., Ind.
{Government Surveys, Base, Meridian, Township, Section or Harbor Line
Street, Block or other Property Line
Survey Lines
Red
Preliminary
Location
Center Lines
Original (Tracker / Setter) Center Line
If Monumented, Show Location and Proper Symbol.
Company Property Line
Fence (on Street Line)
State Kind and Height
Fence (on Company Property Line)
State Kind and Height
Section Corner
17 16
20 21
Section Center
Triangulation Station or Transit Point
Bench-Mark
B.M. X 1232
Stone Monument
Iron Monument
Stone Fence
Board Fence
Give Height
Picket Fence
do.
Barb-Wire Fence
do.
Rail Fence
do.
Worm Fence
do.
Woven Wire Fence
do.
Snow-Fence
do.
Snow-Shed
City
Village
City Limits
Fire Limits

Fig. 225.—Boundary and survey lines.

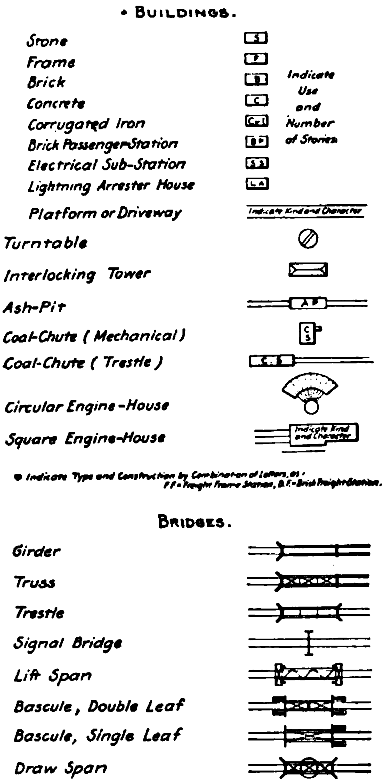


FIG. 226.—Bridges and buildings.

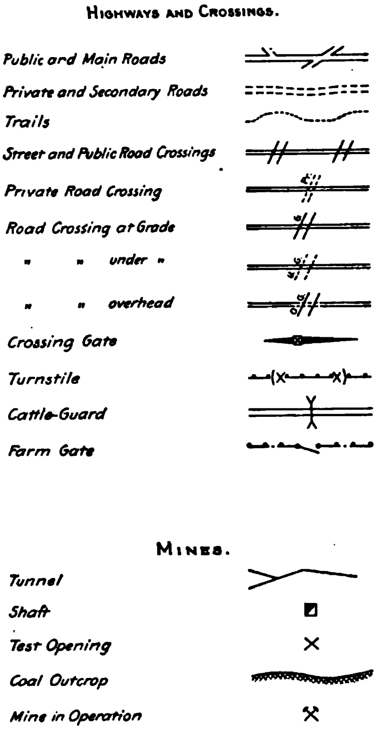


FIG. 227.—Highways, crossings, and mines.

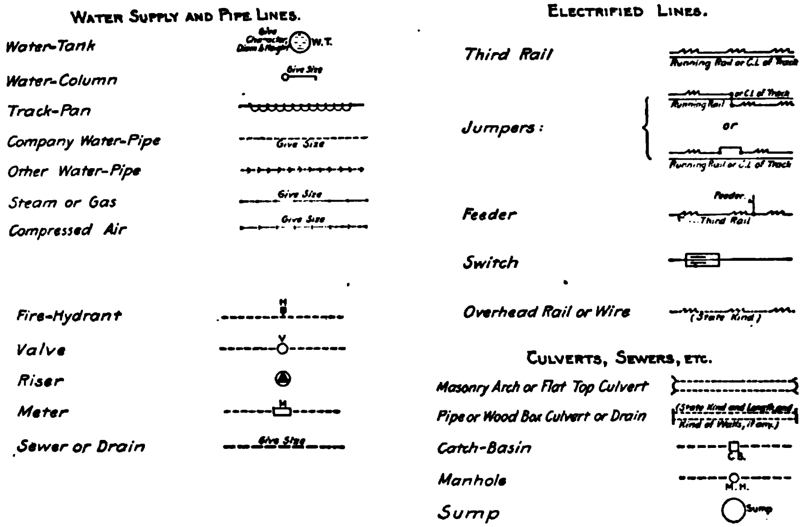


FIG. 228.—Electrified lines, culverts, sewers, water supply and pipe lines.

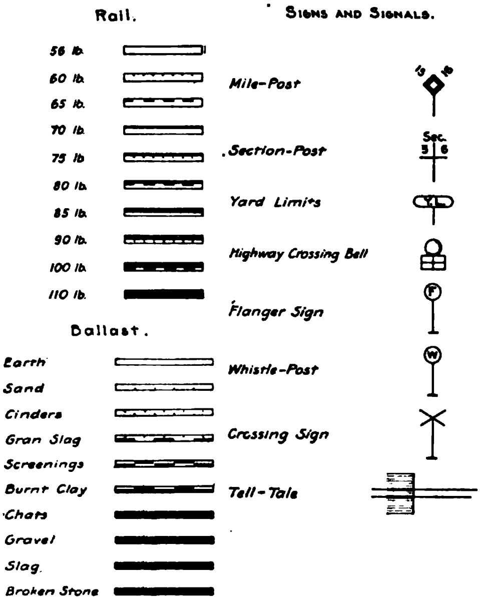


Fig. 229.—Rail, ballast, signs, and signals.

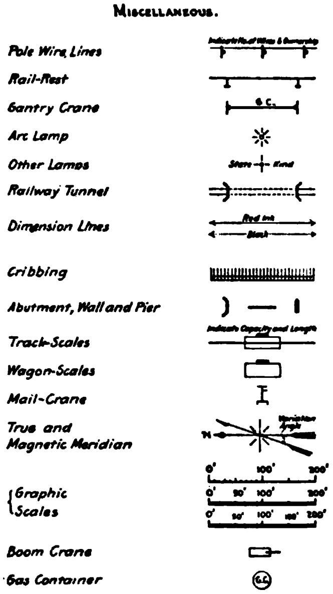


Fig. 230.—Miscellaneous.

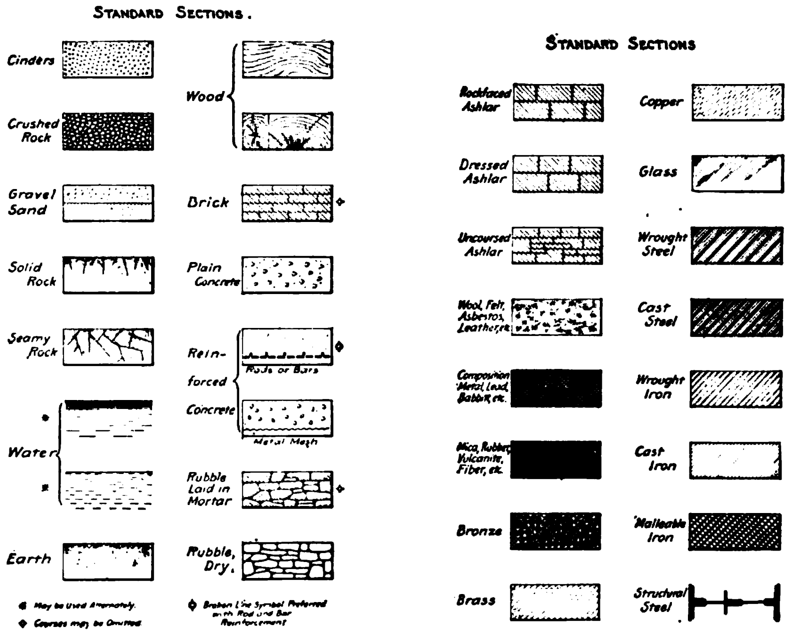


Fig. 231.—Standard sections of materials.

the point of consumption will be a minimum. The greater part of the materials is consumed in maintenance of way and maintenance of equipment. Hence the storekeeper should be closely associated with the heads of these departments. This is accomplished in some organizations by having the engineer of maintenance of way, master mechanic, and storekeeper report to the same official.

CHAPTER XX

ACCOUNTS

275. Classification of Expenses.—Accounts are statements required to enable payments to be made for labor performed and material received, or to establish the detail, total, and comparative cost of various classes of expenses. Expenses of steam-railways are classified by the Interstate Commerce Commission under the headings of *Investment in Road and Equipment* and *Operating Expenses.* Three general accounts are provided for Investment in Road and Equipment, namely,

I. Road.
II. Equipment.
III. General Expenditures.

Operating expenses are divided into eight general accounts, namely,

I. Maintenance of Way and Structures.
II. Maintenance of Equipment.
III. Traffic.
IV. Transportation—Rail Line.
V. Transportation—Water Line.
VI. Miscellaneous Operations.
VII. General.
VIII. Transportation for Investment—Credit.

The classification of expenses of railways prescribed by the Department of Railways and Canals of Canada is practically the same as that prescribed by the Interstate Commerce Commission.

The expenses of the departments of construction and maintenance of way are covered by the two general accounts, *Road,* under Investment in Road and Equipment, and *Maintenance of Way and Structures,* under Operating Expenses.

276. Road.—This account, as well as the two other general accounts of Investment in Road and Equipment, is designed to show the investment of the carrier in property devoted to transportation service. Physical property other than transportation property is not included. The carrier's records must be kept in such form that expenditures for additions and betterments may be reported separately from those for original equipment, original road, and road extensions. To the accounts under Investment in Road and Equipment are charged the cost of the original road; extensions, additions, and betterments; and original equipment.

Construction includes all processes associated with the acquisition and construction of the original road and equipment, road extensions, additions, and betterments.

Original road means the land and improvements covered by the original plan for constructing the new road and carried out as planned.

Original equipment means equipment provided for in the original plan for constructing the new road.

Road extensions mean the land and improvements provided for in the original plan for the construction of extensions of existing main line, additional branch lines and extensions of existing branch lines. Deferred improvements provided for in the original plan, when acquired should be considered as additions.

Additions are additional facilities, such as additional equipment, tracks, bridges, buildings and other structures; additions to such existing structures, such as extensions to tracks, buildings, etc.; additional ties laid in existing tracks; and additional devices applied to facilities, such as the application of rail-anchors to unanchored track. When property, such as a section of track, a building, or other structure, is retired from service and replaced with property of like purpose, the new property must be considered as an addition. If, however, the property retired is of minor importance and is replaced with a structure of like kind without betterment, the cost of replacement should be charged to operating expenses.

Betterments are the improvements of existing facilities through the substitution of superior parts for inferior parts retired, such as the use of heavier rails when relaying rails, and the strengthening of bridges by the substitution of stronger members. The proportional part of the total cost of the substitution chargeable to betterments is the excess cost of the new parts over the cost at current prices of new parts of the kind retired.

277. Primary Accounts of Road.—The general account *Road* is divided into forty-seven primary accounts, a brief description of which follows.

1. *Engineering.*—This includes the pay and expenses of engineers, assistants, and clerks engaged in the survey and construction of new lines and extensions, or in making additions and betterments. It includes the cost of minor equipment used and supplies consumed by these persons, such as field equipment of surveying parties, drafting instruments and supplies, etc.

2. *Land for Transportation Purposes.*—This includes the cost of land for right-of-way, stations, shops, borrow-pits, waste-banks, snow-fences, wharves and docks and the riparian rights therefor; and the cost of removing from the right-of-way and location elsewhere the property of others. Proceeds of the sale of timber or other improvements purchased with the right-of-way should be credited to the account.

3. *Grading.*—The cost of clearing and grading the roadway, and of constructing protection of a permanent character for roadway, tracks, embankments, etc., such as berm ditches, breakwaters, bulkheads, and cribbing, is included in this account.

4. *Underground Power Tubes.*—This includes the cost of power tubes or conduits for underground contacts of electric railways or underground cables for cable railways.

5. *Tunnels and Subways.*—The cost of tunnels and subways for the passage of trains, including ventilating and lighting, is covered by this account.

6. *Bridges, Trestles, and Culverts.*—This includes the cost of the substructure and superstructure of bridges, trestles, and culverts which carry the tracks over watercourses, railways, and highways.

7. *Elevated Structures.*—This includes the cost of elevated structures other than earthwork, used for the purpose of elevating tracks above streets, and which are not properly classable as bridges.

8. *Ties.*—This includes the cost of all track- bridge-, and switch-ties used in the construction of tracks; the cost of additional ties subsequently laid in such tracks; and the excess cost of substitute ties used for tie-renewals over the cost to replace in kind the wooden ties removed. The cost of work-train service and labor for distributing and installing should be charged to account No. 12.

9. *Rails.*—This includes the cost of rails used in the construction of all tracks, and the excess cost of heavier rails or rails of improved types or qualities used for renewals over the cost to replace in kind the rails removed. If heavier rails are replaced with lighter rails the difference in cost should be credited to the account. The cost of work-train and labor for distributing and laying is charged to account No. 12.

10. *Other Track Material.*—This includes the cost of all material used in the construction of tracks, except ballast and material charged to foregoing accounts; and the excess cost of heavier or improved material of this class used for renewals over the cost to replace in kind the material removed. Under this heading are included track fastenings, bumping-posts, crossings, frogs, switches, switch-stands, guard-rails and track insulators.

11. *Ballast.*—This includes the cost of all material used for ballasting tracks, and cost of work-train service and unloading; cost of additional ballast applied to a ballasted track; and the excess cost of improved ballast used in renewals over the cost to replace in kind, to the original height and width, the ballast removed.

12. *Track-laying and Surfacing.*—This includes the work-train and labor cost of distributing and installing ties, rails, and other track material in the construction of all tracks, except tracks on car floats and

temporary tracks. It also includes the cost of spreading and surfacing ballast in tracks not previously ballasted.

13. *Right-of-way Fences.*—This includes the cost of right-of-way fences, farm gates, wing-fences, stock-guards, and hedges, on property not previously fenced. Fences around stock-yards, fuel stations, and station-, building-, and shop-grounds are not included.

14. *Snow- and Sand-fences and Snow-sheds.*—This includes the cost of snow-sheds and permanent or portable snow- and sand-fences other than those erected in lieu of right-of-way fences.

15. *Crossings and Signs.*—In this is included the cost of constructing farm crossings, highways, and other railways across the railway's right-of-way, except railways crossing at grade; cost of track signs, crossing gates, crossing warnings, and watch-houses. The cost of structures carrying the tracks of the railway over highways or other railways should be charged to account No. 6.

16. *Station- and Office-buildings.*—The cost of station- and office-structures, and the fixtures and furniture necessary to first equip the buildings for use is included in this account. Office-buildings used exclusively for maintenance of way and maintenance of equipment should be included under accounts Nos. 17 and 20, respectively. The cost of grading grounds, constructing sidewalks, fences, etc., is included in the cost of buildings.

17. *Roadway Buildings.*—This includes the cost of all buildings used exclusively in the work of maintenance of way and structures. It includes all machinery, fixtures, and furniture to equip the buildings ready for use.

18. *Water Stations.*—The cost of structures, facilities, and appliances used for supplying water for all purposes, except to shops, power-plants, stations, hotels, or section-houses, or temporary water stations used during construction, is included. The exceptions noted should be charged to the accounts relating to the property supplied.

19. *Fuel Stations.*—This includes the cost of all structures and facilities, other than tracks, for supplying fuel to locomotive and floating equipment. The exceptions mentioned under account No. 18 also apply to this account.

20. *Shops and Engine-houses.*—This includes the cost of buildings used as shops, engine-houses, and storehouses for maintenance of equipment; furniture and fixtures of same; and plants for heat and light; but not shop machinery.

21. *Grain Elevators.*—This includes the cost of large structures for the handling and storage of grain, and the necessary machinery and fixtures. Small storage elevators at way stations are classed as station-buildings.

22. *Storage Warehouses.*—This includes the cost of buildings, with

machinery and fixtures, which the railway operates commercially as storage warehouses. Ordinary warehouses for receiving freight for shipment are not included.

23. *Wharves and Docks.*—This includes the cost of wharves, docks, dry docks, slips, float bridges, and other landings for floating equipment; necessary dredging; piling, pile protection, cribs, cofferdams, and other necessary devices and apparatus for the operation and protection of wharves and docks. The cost of coal and ore wharves is not included. The cost of land and riparian rights is included in account No. 2. The cost of buildings, tracks, etc., located on wharves must be charged to the appropriate accounts.

24. *Coal and Ore Wharves.*—This includes the cost of wharves and docks for the handling and storage of coal, and the necessary dredging, machinery, and fixtures. Small transfer or storage trestles or wharves at stations where coal is stored or delivered are classed as station-buildings.

25. *Gas-producing Plants.*—The cost of gas-producing and gas-compressing plants, and machinery and other apparatus in such plants, is included.

26. *Telegraph and Telephone Lines.*—This includes aerial, underground, and submarine telegraph and cable lines and terminal equipment.

27. *Signals and Interlockers.*—This includes the cost of interlocking, block, and other signal apparatus for governing the movement of trains, and towers and other buildings used exclusively for the same purpose. Signal apparatus located in a station-building should be considered as part of the building.

28. *Power Dams, Canals, and Pipe Lines.*—This includes the cost of all dams, canals, pipe lines, and accessories used in the development of water-power for operating trains, and to furnish power, heat, and light for general purposes.

29. *Power-plant Buildings.*—This includes the cost of the buildings of power-plants used to furnish power to operate trains, and to furnish power, heat, and light for stations, shops, or general purposes. Power-plant machinery is covered by account No. 45.

30. *Power Substation Buildings.*—This includes the cost of buildings of power substations used to transmit power for the purposes enumerated under account No. 29.

31. *Power Transmission Systems.*—This includes the cost of all high-tension transmission systems for transferring power from power-plant to place where it is transformed for propelling trains, or for light, heat, power, etc. That part of the transmission system within power-plants is considered as part of the building.

32. *Power Distributing Systems.*—This includes the cost of all distributing systems for conveying low-tension electric power from power-

plants or transformers, and for conveying steam and compressed air from power-plants to point of consumption.

33. *Power Line Poles and Fixtures.*—This includes the cost of poles, cross-arms, insulating pins, and other pole fixtures; braces for the poles; and structures supporting the overhead electric construction.

34. *Underground Conduits.*—The cost of conduits required for underground wires of electric railways, with manholes, sewer connections, and other details necessary for the conduit system are included.

35. *Miscellaneous Structures.*—The cost of all permanent structures not provided for elsewhere, including all fixtures and furniture, is covered by this account.

36. *Paving.*—This includes only the cost of paving about tracks in public highways along which the tracks are laid. Paving within the grounds of stations or other structures is included in the cost of the structures. Paving at highway crossings is charged to account No. 15.

37. *Roadway Machines.*—This includes the cost of the initial outfit of roadway machines provided for the maintenance of way and structures and additional roadway machines acquired subsequently. When new construction or extensive addition and betterment work necessitates the purchase of roadway machines to be used exclusively thereon, the cost should be included in the cost of the work. The amount realized from subsequent sale or the appraised value after the work is completed should be credited to the cost of the work. Roadway machines are discussed at length in Arts. 258 to 262.

38. *Roadway Small Tools.*—This includes the cost of the initial outfit of roadway and track tools provided for maintenance of way and structures at the time the railway is opened for traffic. Roadway tools are discussed at length in Arts. 251 to 256.

39. *Assessments for Public Improvements.*—The railway's assessed proportion of the cost of constructing public improvements, such as grading, sewering, paving streets, and other public improvements, is charged to this account.

40. *Revenues and Operating Expenses during Construction.*—The cost of operating a section of railway prior to the regular operation of revenue trains, including rent and repair of equipment used in commercial service is charged to this account. The amounts collected for rents and for transportation on construction trains, and the net profits from commissary outfits, etc., are credited to the account.

41. *Cost of Road Purchased.*—This is a clearing account which is used only temporarily to carry the cash cost of a road or portion thereof purchased, until a plan is approved for distributing the cost to the primary accounts. Equipment is not included. Considerations other than cash must be valued on a current cash basis.

42. *Reconstruction of Road Purchased.*—The cost of rebuilding a purchased road to bring it up to a higher standard is charged to this account. When the entire work is completed the cost is credited to this account and charged to the proper primary accounts.

43. *Other Expenditures—Road.*—To this account is charged the cost of all items not properly included in any of the foregoing accounts as a part of any specific work, such as the cost of transporting the company's men, materials, and supplies; rental of certain equipment; injuries to persons during construction, and similar items.

44. *Shop Machinery.*—This includes the cost of all machinery and apparatus in shops and engine-houses; special foundations for and installation of same; and initial equipment of small hand-tools.

45. *Power-plant Machinery.*—This includes the cost of machinery and other apparatus for generating power, in a self-contained building, used to operate trains, or to furnish power, heat, and light for stations, shops, or general purposes, including the cost of special foundations and installation of machines.

46. *Power Substation Apparatus.*—This includes the cost of machines and other apparatus—such as rotary converters, storage batteries, switch-boards, and transformers—including special foundations and installation—for storing or transforming power in power substations used to operate trains, and for power, heat, and light for stations, shops, etc.

47. *Unapplied Construction Material and Supplies.*—The cost of all material and supplies located at the point of use for constructing new roads and extensions is charged to this account. The purpose of the account is to exclude from the current assets the cost of this material, under the assumption that it will be used for no other purpose.

278. Maintenance of Way and Structures.—The general account of *Maintenance of Way and Structures* is divided into seventy-nine primary accounts designed to show the cost of maintenance of the various items and the loss through depreciation. Distinct maintenance accounts are provided for expenses of a general character, such as superintendence, injuries to persons, insurance, stationery and printing, etc., which have no depreciation.

The cost of repairs provided for in the several repair accounts includes the cost of inspection to determine the repairs necessary, and of adjusting, repairing or replacing parts, such as frogs and switches, or the replacing of ties, rails, etc., in tracks; the cost of inspection and testing after repairs have been made; incidental cost of repairs, such as the construction and removal of false work; cost of relocating fixed improvements; cost of demolishing retired fixed improvements and disposing of the material; cost of protecting traffic during the progress of addition and betterment work; cost of laying out, caring for, and restoration of seasonal features of the grounds of buildings, and the repair of adjacent sidewalks, driveways, and streets; and cost of removing casual incumbrances, such as snow, land slides, etc.

279. Classification of the Cost of Repairs.—The several items entering into the cost of repairs may be classified as follows:

(*a*) *Cost of labor* includes the amount paid for labor of the railway's employees and, unless specified in the particular primary account, the cost of boarding, traveling, and incidental expenses of the employees.

(*b*) *Cost of materials and supplies* includes the cost of materials, small tools, and supplies delivered to the railway, and a proportion of store expenses. The cost of transportation of these by the company is not included. In calculating the cost of materials used allowances must be made for unused portions and for the value of material recovered from property retired and from temporary structures used in repair work.

(*c*) *Cost of work-train service* includes the wages of enginemen, trainmen, and engine-house men; and the cost of fuel and supplies consumed in the operation of work-trains.

(*d*) *Cost of floating equipment work service* includes the wages of crews and fuel and supplies consumed in the operation of floating equipment work service.

(*e*) *Cost of special machine service* includes the wages of crews and cost of materials and supplies consumed in operating steam-shovels, rail-unloaders, ballast-unloaders, pile-drivers, ditching-machines, dredges, and other labor-saving machines; also rents paid for the use of such machines.

(*f*) *Cost of contract work* includes the cost of work done under contract by other companies or individuals, and expenses incident to the award of the contract.

(*g*) *Cost of privileges* includes the amounts paid for temporary special privileges in connection with the repairs of the railway's property.

(*h*) *Cost of protection from casualties* includes expenditures for protection against damage by fire, flood, etc., such as rewards paid for extinguishment of fires, cost of prosecuting incendiaries, amounts paid municipalities for fire protection, and other similar items of expense. It does not include insurance premiums.

280. Depreciation of Fixed Improvements.—Fixed improvements are all structures which are fixed as to location, such as tunnels, bridges, buildings, earthworks, etc. Depreciation accounts are provided for creating reserves which will meet or reduce the amounts that would otherwise be charged to operating expense or to profit and loss to cover property retired. The depreciation charges must be based upon the percentage of the original cost, ledger value, or purchase price and the railway's experience as to actual current loss from depreciation. An explanation of the bases of the charges must accompany the report.

281. Primary Accounts of Maintenance of Way and Structures.—These accounts are numbered from 201 to 279. Accounts Nos. 202 to 219 and 221 to 270, inclusive, really are in duplicate, the first part showing the cost of repairs and the second part showing the depreciation; that is, account No. 202 is *Roadway Maintenance* and No. 203 is *Roadway—Depreciation*, No. 204 is *Underground Power Tubes* and No. 205 is *Underground Power Tubes—Depreciation*, and so on to No. 269, *Roadway Machines* and No. 270, *Roadway Machines—Depreciation*, except account No. 220, which has no accompanying depreciation account. The remaining accounts are the distinct maintenance accounts mentioned in Art. 278. The following list gives a description of only the accounts which differ from those described in Art. 277.

201. *Superintendence.*—This account includes the pay of officers in charge of or engaged in the maintenance of way and structures; the pay of clerks and other employees in the offices and on the business cars of officers whose pay is charged to this account; and office and other expenses of these officers and employees. Surveying and drafting instruments are classed as supplies under this account.

202. *Roadway Maintenance.*—This includes all costs of repairing the roadbed, such as blasting rock, building and removing temporary tracks around slides and washouts, constructing and cleaning drains and ditches, repairing subgrade in case of washouts, sodding banks, oiling roadbed, removing slides, etc.; cutting and disposing of vegetation on the right-of-way; dressing ballast; plowing and digging fireguards; removing scrap and dirt; and general cleaning of the right-of-way, station-grounds, and yards; policing tracks; repairing bank protection; work-train service in connection with maintenance work; taking up and relocating tracks; and other roadway work not provided for elsewhere, such as general roadway inspection and premiums given in connection with roadway maintenance.

203. *Roadway—Depreciation.*—Alternate accounts from 203 to 219 and 222 to 270 inclusive are for depreciation. The remaining accounts of this nature will not be shown in this list.

204. *Underground Power Tubes.*—See account No. 4, Art. 277.

206. *Tunnels and Subways.*—This includes the cost of repairing, lighting, ventilating, and watching tunnels and subways containing railway-tracks; and special tools and supplies necessary.

208. *Bridges, Trestles, and Culverts.*—This includes the cost of repairing and watching bridges, trestles, and culverts; altering and bracing during process of filling; removing old structures in connection with the construction of new structures; dredging and cleaning water channels for protection; and cleaning culverts. Only bridges, trestles, and culverts which carry the railway's own tracks are included.

210. *Elevated Structures.* 212. *Ties.* 214. *Rails.* 216. *Other Track Material.* 218. *Ballast.* See accounts Nos. 7 to 11, Art. 277.

220. *Track-laying and Surfacing.*—In this account is included the labor cost of preparing roadbed and applying ballast for repair of tracks; unloading, distributing, boring, adzing, and applying ties; disposing of ties released; replacing ties; unloading, distributing, cutting, drilling, adzing for, and laying rails; loading released rails; unloading, distributing, and applying other track material, and gathering up material released; lining, surfacing, gaging, and shimming tracks; tightening track-bolts and track-spikes; restoring tracks in case of washouts and wrecks; taking up and relocating tracks; work-train service in connection with track-laying and surfacing; and miscellaneous track work not otherwise provided for, such as repairing rail-rests, official track inspection, and premiums given for excellence in track maintenance.

221. *Right-of-way Fences.*—See account No. 13, Art. 277.

223. *Snow- and Sand-fences and Snow-sheds.*—This includes the cost of repairing permanent and portable snow- and sand-fences and snow-sheds; and the rental of land for placing snow- and sand-fences.

225. *Crossings and Signs.* 227. *Station- and Office-buildings.* 229. *Roadway Buildings.* 231. *Water Stations.* 233. *Fuel Stations.* 235. *Shops and Engine-houses.* 237. *Grain Elevators.* 239. *Storage Warehouses.* See accounts Nos. 15 to 22, Art. 277. In each of these and subsequent maintenance accounts the cost of maintaining the grounds appurtenant to such buildings or structures is included.

241. *Wharves and Docks.*—This includes the cost of repairing wharves and docks; dredging around and approaches to such structures, and removing dredged-out material; cutting ice in and around such structures; and repairs to cribbings, racks, guards, and other protecting appurtenances. Also see account 23, Art. 277.

243. *Coal and Ore Wharves.* 245. *Gas-producing Plants.* See accounts Nos. 24 and 25, Art. 277.

247. *Telegraph and Telephone Lines.*—This includes the cost of repairs to the railway's telegraph and telephone lines and terminal equipment; and the cost of work-train service and special tools necessary.

249. *Signals and Interlockers.*—This includes the cost of repairing interlocking, block, and other signals governing the movement of trains; repairing of signal towers, etc.; rent and other office expenses of the signal engineers; and traveling expenses of signal engineers and maintainers.

251. *Power-plant Dams, Canals, and Pipe Lines.* 253. *Power-plant Buildings.* 255. *Power Substation Buildings.* 257. *Power Transmission Systems.* 259. *Power Distribution Systems.* 261. *Power Line Poles and Fixtures.* 263. *Underground Conduits.* 265. *Miscellaneous Structures.*

267. *Paving.* 269. *Roadway Machines.* See accounts Nos. 28 to 37, Art. 277.

271. *Small Tools and Supplies.*—This includes the cost of roadway and track tools and the cost of repairing same; also the cost of supplies consumed in connection with the operation of roadway machines while used in repairing roadway and track; and cost of supplies used by trackwalkers, watchmen, and track repair men. Supplies are distinct from materials in that they are considered as being consumed by one use. Roadway and track tools are fully described in Arts. 250 to 256. Supplies are described in Art. 257.

272. *Removing Snow, Ice, and Sand.*—The cost of keeping the track clear of snow, ice, and sand is charged to this account. It includes the cost of distributing, setting up, moving, taking down, regathering, and storing, snow- and sand-fences; preventing the accumulation of snow, ice, and sand; cost of snow-plow, flanger, and work-train service; applying and removing flangers and pilot-plows to cars or locomotives; salt for switches; and board and lodging for men employed in this work.

273. *Assessments for Public Improvements.*—See account No. 39, Art. 277.

274. *Injuries to Persons.*—To this account are charged all expenses incurred on account of injuries to persons which occurred directly in connection with the maintenance of way and structures, including injuries occurring in connection with the operation of work-trains in such service, and injuries caused by defective highways within the right-of-way. It also includes expenses because of injuries to employees while demolishing structures, the maintenance of which is charged to this general account; expenses of employees and others called in consultation or as witnesses in damage suits; and 25 per cent. of the donation to hospitals. The remaining hospital donations are distributed 25 per cent. to *injuries to persons* under *Maintenace of Equipment* and 50 per cent. to *injuries to persons* under *Transportation—Rail line.*

275. *Insurance.*—This includes all premiums, except reinsurance premiums, for insuring the railway against loss through injuries to persons, or damage to or destruction or loss of property, when such loss would be chargeable to maintenance of way and structures; also fidelity bonds of employees in this department. Amounts of insurance recovered should be credited to the account.

276. *Stationery and Printing.*—The cost of all stationery and printing used for maintenance of way and structures is charged to this account. It includes the cost and repairs of calculating-machines, addressographs, copying-presses, dictaphones, mimeographs, pencil-sharpeners, postage, typewriters, blank books and forms, pens, letter paper, ink, etc.

277. *Other Expenses.*—All expenses in connection with maintenance of way and structures not provided for elsewhere are charged to this

account. It includes the pay and expenses of employees of this department attending conferences concerning wage disputes; fees paid arbitrators in wage disputes; payments to employees for time absent on account of sickness not covered by account No. 274; gratuities paid to persons for discovering defective rails, misplaced switches, etc.

278. *Maintaining Joint Tracks, Yards, and Other Facilities—Dr.*—This includes the railway's proportion of the costs incurred by others in maintaining joint tracks, yards, terminals, and other facilities.

279. *Maintaining Joint Tracks, Yards, and Other Facilities—Cr.*—This includes the amounts chargeable to others as their proportion of the cost incurred by the railway in maintaining joint tracks, yards, terminals, and other facilities.

CHAPTER XXI

ANNUAL PROGRAM FOR MAINTENANCE OF WAY AND STRUCTURES

282. Determination of Work to be Done.—The amount of money spent by a railway per unit length of track depends primarily upon the standard of perfection of the work required and the materials used, which, together, are spoken of as the standard of maintenance. It is generally true that this standard is the resultant of two forces, first, the belief of the engineer of maintenance of way or the chief engineer that a certain standard of maintenance is necessary for the track to bear the proper relation to the traffic carried; second, the unwillingness or inability of the highest executive officials to appropriate for maintenance purposes the amounts desired by the engineer. As the appropriations reflect the financial condition of the railway, it may happen, therefore, that the standard of maintenance fluctuates from year to year.

The fundamental purpose of maintenance of way and structures, as well as all other activities of a railway, is to make possible the transportation of freight, passenger, and other traffic at a profit. The immediate objects of the expenditures for maintenance of way and structures are:

1. To insure the safe passage of trains at normal speeds; and otherwise prevent accident to persons and property.
2. To prevent deterioration of track and structures.
3. To increase the company's facilities.
4. To reduce future maintenance expenses; and for special purposes.
5. To improve the appearance of the property.

Carrying on the work of maintenance consists of three general operations:

(*a*) Fixing the standard of maintenance. This must be done by the engineer of maintenance of way or the chief engineer in consultation with the executive officials.

(*b*) Determination of the work to be done. The final decision of this must rest with one man, preferably the person who fixes the standard of maintenance.

(*c*) Execution of the work determined upon.

It is impossible for one man to keep in touch with the many details of maintenance on a large railway system. The present method used to determine the maintenance of way program for the ensuing year has been developed to place in the hands of one man, who has the final authority to determine the work to be done, the knowledge of details possessed by subordinates in close touch with the work. The details of the procedure have been worked out along slightly different lines on various railways but the general features are the same. The procedure is described in the following articles, but it should be borne in mind that the system outlined is general and may differ in some details from the practice of different railways.

283. Maintenance of Structures Program.—During the fall of each year, usually not later than November 1, a report containing recommendations for maintenance work required on structures for the following calendar year, based on the annual or second semi-annual general bridge inspection (see Art. 265) are sent to the engineer of maintenance of way. The data contained in the report are based on a detailed inspection of every structure on the railway, made personally by the engineer of bridges and buildings, master carpenter or general foreman of bridges and buildings, according to the organization, in company with the division engineer. Various railways base the recommendations upon inspections as follows:

(*a*) Structures are given a general semi-annual inspection on the Chicago and Northwestern Railway. The spring inspection is made by the superintendent of bridges and buildings and the fall inspection is made by the same official in company with the division engineer and two or more bridge men. The annual program is based on the fall inspection. The spring inspection is made as a check on the fall inspection and such additional repairs as may be considered actually necessary for the safety of traffic—the necessity for the repairs having developed during the winter—are added to the program. Both inspections are made with a motor-car.

(*b*) Three routine inspections of structures are made each year on the Michigan Central Railroad. Early in the spring all structures are inspected by the bridge-foreman of the division; in the middle of the summer they are thoroughly inspected by the regular bridge-inspector; in the fall they are inspected by the bridge engineer accompanied by the regular inspector and the bridge-foreman of the division. The recommendations for the next year's program are based on the fall inspection.

(*c*) On the Missouri Pacific Railway an inspection is made in the fall of each year by the engineer of bridges and buildings for the purpose of making up the program of work required for the ensuing year.

(*d*) On the Erie Railroad, late in the summer the engineer of the division, accompanied by a master carpenter, inspects all structures and reports on the work required for the following year. Similar inspections are made on the track each spring as soon as the frost is out of the ground. From these reports the engineer of maintenance of way prepares a definite program, arranged to show the date at which each part of the work is to be done. When the work shown on the program is executed, it must be completed on or before the date given in the program. The division engineers send daily reports to the engineer of maintenance of way, advising him of the progress on each job. The program is used also as a schedule for shipping materials. By so doing much delay from waiting for materials is eliminated. Late in the fall the engineer of maintenance of way, accompanied by division engineers, supervisors, and foremen, makes an inspection during which the work of the past season and proposed improvements for the next season are discussed.

(*e*) Semi-annual routine inspections are made on the Nashville, Chattanooga and St. Louis Railway. The minor repairs for the summer are determined from the spring inspection. The fall inspection is made as a basis for the next year's program. The two inspections are made by the supervisor of bridges and buildings or assistant division engineer in charge of structures. Recommendations based on the fall inspection are immediately sent to the chief engineer, who, in company with the supervisor or assistant engineer having charge of the structures on the division, at once commences a personal examination of every structure for which important recommendations have been made, and decides whether to approve the recommendations or not.

The reports, which are tentative divisional programs, should have each item of repair-work listed separately under the following appropriate headings, corresponding to the classification of accounts given in Arts. 277 and 281:

(*a*) Tunnels and subways (accounts Nos. 4 and 206).

(*b*) Bridges, trestles, and culverts (accounts Nos. 5 and 208).

(*c*) Elevated structures (accounts Nos. 7 and 210).

(*d*) Ties (accounts Nos. 8 and 212). This item includes only the cost of bridge-ties and other ties used by the bridge department for repairs on bridges, trestles, wharves, turntables, etc.

(*e*) Snow- and sand-fences and snow-sheds (accounts Nos. 14 and 223).

(*f*) Crossings and signs (accounts Nos. 15 and 225).

(*g*) Buildings (accounts Nos. 16 to 22, 25, 28 to 30, and 35, and corresponding maintenance accounts).

(*h*) Wharves and docks (accounts Nos. 23, 24, 241, and 243).

Each of these should be subdivided to show the cost of each class of labor and kind of material. The different classes of labor would be iron-work, carpentry, general painting, metal-painting, masonry, etc.

The complete recommendation should show:

1. The location of the structure, each structure being listed in the order of progression of the bridge-numbers.

2. A description of the structure.

3. A description of the proposed work on the structure.

4. A detailed estimate of the proposed work, as outlined above.

5. The purpose for which the work is to be done, or the "class-number," according to the five purposes enumerated in Art. 282. The class-number is used as an abbreviation. If the work described is shown as coming under class-number 5 it means that the work proposed is for the purpose of improving the appearance of the property, and similarly for the other class-numbers.

6. When the class-number shows the work is to be done to reduce future maintenance expense or for special purposes, the estimates for that structure should consist of the following three parts:

(*a*) *Estimate* 1 should show the repairs necessary for the ensuing year according to class-numbers 1 and 2.

(*b*) *Estimate* 2 should show the character of the structure or parts which it is proposed to substitute for the existing structure.

(*c*) *Estimate* 3 should show the cost to completely renew the structure in kind.

The excess of Estimate 2 over Estimate 3 is the value of the addition or betterment proposed. A complete new structure of improved quality is an addition. Existing parts replaced with improved parts constitute a betterment. As an example of the three estimates, suppose it is proposed to substitute a 30-ft. concrete arch culvert for an eight-bent frame trestle. The estimates would be arranged as follows:

Estimate 1.	Repairs: 12 ties, 2 caps, 3 20-ft. posts, 50 ft. of 3-in. by 8-in. bracing....		$90.00
Estimate 2.	30-ft. concrete arch, shifting track, filling, removing trestle..........	$10,000	
	Value of material released.........	500	
		$9,500	$9,500.00
Estimate 3.	Estimated cost to replace in kind....		$1,250.00

As soon as the reports containing the tentative programs are received by the chief engineer or engineer of maintenance of way either he commences a personal inspection of the property, stopping at all structures where the program recommends work to be done, or he may transmit the reports to the engineer of bridges and buildings, who will make the inspection. On this final inspection the class-number is revised where the engineer thinks the original number did not properly describe the purpose for which the work is to be done and such other notes are made as will aid in determining what changes in the amount of expenditure can be made if the final application for expenditure is not approved entirely. In this way the detail work of inspection and the preparation of the program is done by subordinate officials while the highest official of the department utilizes his superior knowledge to check that of his division engineers, superintendent of bridges and buildings, etc. After completing the check inspection the final application for expenditure is prepared, being a summary of the corrected divisional programs.

284. Maintenance of Way Program.—The principal expenditures for maintenance of way are for:[1]

(*a*) Ballast, ties, rails, track fastenings, frogs, and switches.

(*b*) Labor of applying these materials.

(*c*) Labor of keeping these materials in their proper relation to each other, after they have been applied.

(*d*) Policing, cleaning, necessary tools, and miscellaneous.

Though the program for Maintenance of Way should be prepared with the same care exercised in preparing the program for Maintenance of Structures, the character of the materials, labor, and accessories affected is such that the same detailed inspection immediately preceding the preparation of the program is unnecessary.

In general, the method pursued in determining the work to be done and preparing the program is similar to that already described for the Maintenance of Structures program. The actual determination of the track work to be done rests in a large measure with the division engineer and roadmaster. About the first of November of each year the division engineer sends reports to the engineer of maintenance of way which state the number of ties and quantity of rail, track fastenings, ballast, and miscellaneous materials and supplies required for the following year. The report of ties is based on a careful inspection, as described in Art. 58, and should state the total number and the number of first-class, second-class, treated, and softwood ties and switch-ties required. The rail report should give the total tonnage of each section of rail required; total mileage of each section renewed; and the year in which rails to be renewed were laid and the mileage laid that year. Frogs, switches, and track fastenings are usually renewed at the same time rail is renewed. These should be included in the estimate for track fastenings. The ballast report should show the kind and quantity required and purpose for which it is to be used, such as replacing inferior ballast or raising track. The three items of these reports particularly scrutinized by the engineer of maintenance of way are ties, rail, and ballast. If he approves the reports they become the application for expenditure and are sent to the proper financial official, who, if he approves the application, signs the authority for expenditure.

285. Reduction of the Annual Program.—Before approving the final application for expenditure, the engineer of maintenance of way should carefully go over the tentative program and compare the proposed expenditures with those of previous years and study the results obtained thereby. As these reports are by divisions, it is easy for him to compare the results obtained from similar expenditures on different divisions. He is thus aided in determining the relative needs of the various divisions, and this information is taken into consideration in making out the application for expenditure and in apportioning available funds.

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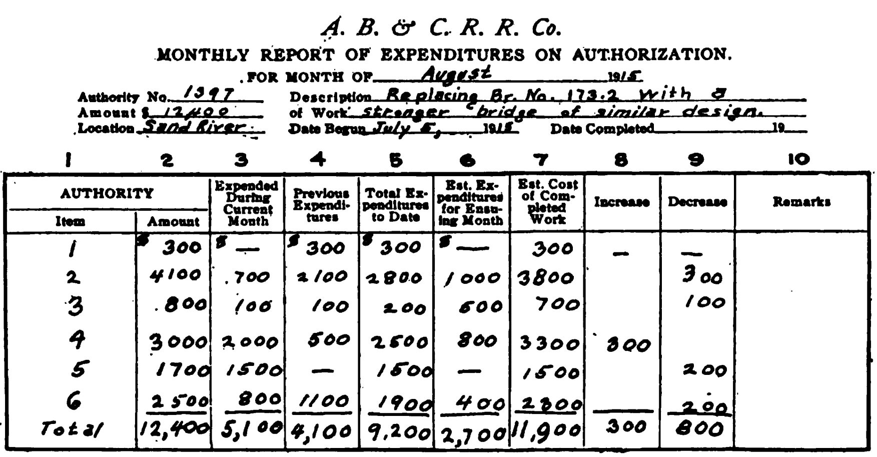
[1] Economics of Railway Operation, by M. L. Byers, page 242.

It frequently happens that the program as outlined exceeds the amount appropriated. It is then necessary to systematically reduce the cost of the program. The usefulness of the class-numbers shown in the program will now be apparent. The first items to be eliminated from the program would be those intended to improve the appearance of the property, class-number 5. If these are eliminated, the cost of future maintenance and the earning power of the property will be affected only slightly, if at all, and the capacity of the property to carry traffic safely will be unaffected. If the cost of the program is still too large, those items intended to reduce future maintenance expenses, class-number 4, would be eliminated next. Though reducing future expenses, present expenses would be increased by doing the work in accordance with the program. The three estimates accompanying this class of items show this. Referring to the example in Art. 283, the annual interest at 5 per cent. on the cost of the proposed concrete culvert would be $475.00. Hence there would be a saving of $475 – $90 = $385, to make the necessary repairs and retain the trestle for another year The annual interest on the cost of replacing the structure in kind would be $62.50, but, besides this interest, after the first year the cost of renewals would increase yearly so that the future maintenance expenses would not be decreased. A concrete structure is considered permanent and the yearly maintenance cost is little or nothing. The total immediate saving by repairing the trestle would be $9500 – $90 = $9410.

After eliminating all items of this kind, if the cost of the program is still too high, the items intended to increase the company's facilities, class-number 3, such as the installation of block signals or interlocking plants, laying heavier rails, installing track-tanks, double-tracking, etc., can be eliminated. If the program is still too large, items intended to prevent deterioration, class-number 2, such as the painting of wood and metal structures and the protection of overhead structures from locomotive blasts and gases, can be eliminated as a last resort. If the program has been carefully prepared no other items can be eliminated, as it is impossible to eliminate the items affecting safety, class-number 1.

286. Execution of the Work.—After the program is finally decided upon and the authority for expenditure obtained, a copy of the authority is sent to each division engineer as his authority for the following year's work. If part of the work to be done is to be charged to maintenance and part to additions or betterments, the authority will state the amount to be charged to each. When the work is being done the amount to be charged to additions or betterments is first charged out, being debited to the proper primary accounts under Investment in Road and Equipment. All remaining expenses of the same work will be charged to the proper primary accounts under Maintenance of Way and Structures.

After the division engineer receives his authority, he issues authorities of a similar nature to his supervisors when he is ready to have the various items of work done. These state the amount of expenditure authorized for the work and are the authority for the supervisor to have the work done at once. After receiving the authority, at the end of each month the engineer in charge of the work should report to the division engineer the amount of the authority expended during the month. This is the monthly report of expenditures on authorization described in Art. 267. Its use is illustrated by Fig. 232. The percentage of authority expended to date is found by dividing the total of column 5 by the total of column 2, and is $\frac{9200}{12,400}$ = 74.2 per cent. Column 7 shows the probable cost to execute the program. Dividing this total into the total expenditure to date gives the percentage of work authorized which has been completed to date, and is $\frac{9200}{11,900}$ = 77.3 per cent. The cost of the work done, in percentage of the authorized cost, is $\frac{74.2}{77.3}$ = 96 per cent.



A. B. & C. R. R. Co.

MONTHLY REPORT OF EXPENDITURES ON AUTHORIZATION.

FOR MONTH OF August 1915

Authority No. 1397 Description of Work Replacing Br. No. 173.2 with a stronger bridge of similar design.

Amount $ 12400

Location Sand River. Date Begun July 5, 1915 Date Completed 19

1	2	3	4	5	6	7	8	9	10
AUTHORITY		Expended During Current Month	Previous Expenditures	Total Expenditures to Date	Est. Expenditures for Ensuing Month	Est. Cost of Completed Work	Increase	Decrease	Remarks
Item	Amount								
1	$ 300	$ —	$ 300	$ 300	$ —	300	—	—	
2	4100	700	2100	2800	1000	3800		300	
3	800	100	100	200	600	700		100	
4	3000	2000	500	2500	800	3300	300		
5	1700	1500	—	1500	—	1500		200	
6	2500	800	1100	1900	400	2300		200	
Total	12,400	5,100	4,100	9,200	2,700	11,900	300	800	

FIG. 232.—Monthly report of expenditures on authorization.

After the work is completed the engineer in charge sends the division engineer a report of the record cost of the work, similar to that described in Art. 267.

Work is occasionally done without the authority of the division engineer. A monthly report of expenditures must be made of this work, similar to the monthly report of expenditures on authorization, omitting the authority number but showing the name of the person authorizing the work; and after the work is completed a report of the record cost must be made.

By regularly looking over the monthly reports of expenditures and the reports of the record cost, the division engineer can keep in touch with all work being done on his division and can compare the total expenditures at any time with his authority for expenditure.

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NOTE.—The index is arranged to show the relative importance of the references under each entry. The references are divided into three classes: Those of first importance are printed in bold face type and refer to topics given a complete treatment or of major importance according to the scope of the book. Those of second importance are printed in *italics* and refer to topics given a less complete treatment or of less importance according to the scope of the book. Those of third importance are printed in ordinary type and refer to topics given a brief or general treatment. All numbers refer to pages.

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